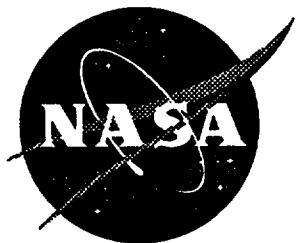


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Property Evaluation of LTM25 Composite Materials

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1.0 Introduction

This report summarizes the work performed on the contract NAS1-19347, Task 14. Northrop Grumman Corporation was contracted by NASA Langley to conduct testing on composite materials that cure at low temperatures. These materials are being incorporated into Unmanned Aerial Vehicles (UAVs) to reduce manufacturing costs since it allows the use of low-cost tooling and facilities. Two composite prepreg product forms were evaluated; MR50/LTM25 unidirectional tape, batch 588cu and CFS003/LTM25 woven cloth, batch 1661. Both product forms were manufactured by the Advanced Composite Group, Inc. and were supplied by NASA.

Northrop Grumman fabricated, machined, and tested specimens to determine the properties listed in Tables 1 and 2 for the two material systems. In order to generate the properties requested by NASA, Northrop Grumman developed and executed the test matrix shown in Table 3.

Additional panels listed in Table 4 were fabricated, inspected, and shipped to NASA for further evaluation. The effects of different debulking procedures were evaluated on laminate numbers 13 through 18. These panels were sectioned at Northrop Grumman to determine the resin content, fiber volume fraction, void content, and density. After sectioning, these panels were shipped to NASA as well.

Itemized below is a description of the methods used to manufacture, inspect, and test the specimens. A summary of the test results is also provided.

2.0 Composite Fabrication

All laminates for this effort were fabricated following the procedure listed below:

2.1 Defrosting

All prepreg was completely defrosted before opening each bag of material. The bag was not opened until the material inside the bag did not feel cold to the touch. Great care was taken so that condensation did not interact with the material. Out time for each bag was recorded to the hour.

2.2 Debulking Procedure

The laminates were debulked every four plies according to the following procedure:

- a) One layer of pin pricked A4000 release film was applied to the plies. A4000 release film was pin pricked using a rolling tool (average hole spacing = 0.4" and a minimum hole diameter 0.015"). Material was cut and spliced to avoid bridging.
- b) Two layers of N-10 breather cloth were applied over the plies and pin pricked release film. Material was cut and spliced to avoid bridging.
- c) The lay-up was vacuum bagged while ensuring sufficient slackness was provided in the bagging material to avoid bridging.
- d) A full vacuum was applied (no less than 25" Hg) to debulk the laminate for a period of no less than 15 minutes.

Laminate numbers 14, 16, and 18 were debulked every twenty-four plies for no less than one hour.

2.3 Cure Procedure

The debulked lay-ups were bagged according to the drawing shown in Figure 1. All laminates were cured and post cured according to the procedure illustrated in Figure 1.

In order to eliminate differences in cure cycles for the debulking study, panels 13 and 14 were cured and post cured side-by-side. Likewise, panels 15 and 16 were cured and post cured side-by-side. Similarly, panels 17 and 18 were also cured and post cured side-by-side.

2.4 Tab Material Fabrication

Grip tabs were fabricated from S2 glass/R6376 (MS 519) material. The laminate orientation for the grip tabs was 6 plies of 0° cloth, [0₆]. The grip tab material was cured according to Northrop Grumman B2 Division specification R201. The autoclave temperature was ramped up at a rate of 5°F/minute to 350°F and held for two hours. Pressure of 100 psi was applied at 150°F while the vacuum was vented at 10 psi.

3.0 Ultrasonic Inspection

All laminates fabricated were ultrasonically inspected according to Northrop Grumman's specification IT-89, class A, using a scan resolution of 0.05 inch. The average ΔdB loss of each panel was reported. A summary of the ultrasonic inspection results is provided in Table 5. (Note: the ASDL number used in this and other tables is an identification number assigned to each panel.) Ultrasonic inspection revealed significant amounts of porosity with both product forms. Consequently, the porosity level must be considered when analyzing the data derived from these panels. MR50/LTM25 unidirectional tape, batch 588cu had a physical ridge in the middle of the prepreg approximately 2-4 inches wide along the length caused by either fiber or resin concentration. The phenomenon did not exist over the entire length of the prepreg material. This peculiarity in the material, where it existed, showed up as dark patches in the C-scan.

4.0 Panel and Specimen Machining

Six panels were fabricated for property evaluations conducted at Northrop Grumman. These panels were machined into individual specimens according to the diagrams shown in Figures 2 through 7. Specimens that required tabs were machined as a group so tab bonding could be performed more efficiently. The tabs were bonded with EA 9394 paste adhesive and were cured for two hours at 160°F. Individual specimens were then machined from the bonded sections. Specimen configurations for each of the tests are shown in Figures 8 through 13.

The six panels fabricated for NASA to evaluate the effects of the debulking procedure were machined according to the diagrams shown in Figures 14 through 19. These specimens were used to determine the resin content, fiber volume fraction, void content, and density of the panels.

5.0 Environmental Conditioning

All specimens and spares (except CTE and RC specimens) were dried in a vacuum oven for 5 days at 160°F. The specimens were weighed before and after the drying procedure. For specimens that incorporated grip tabs, traveler specimens that were representative of the gage section (untabbed portion) of the specimens were weighed. After drying, the -125°F and room temperature specimens were stored at 0°F in moisture proof bags until testing was performed.

The 180°F/wet specimens and 3 spares for each test/laminate set were moisture conditioned in a humidity chamber set at 160°F/98% R.H. Specimen moisture content was monitored by weighing the specimens or the travelers. While in moisture conditioning, the specimens and traveler specimens were weighed twice a week. The specimens were moisture conditioned until the equilibrium moisture content was reached. Since empirically determined hygrothermal constants were not available, the equilibrium moisture content was determined when the moisture content remained approximately unchanged. After moisture conditioning, the 180°F/wet and room temperature specimens were stored at 0°F in moisture proof bags until testing was performed.

Since LTM25 is a low temperature curing resin, there was initial concern that the moisture conditioning procedure might degrade the material. To evaluate the effects of the conditioning procedure, rheometric dynamic spectroscopy (RDS) specimens were tested in the dried condition as well as following moisture conditioning to the equilibrium moisture content level (approximately 0.69% and 0.98% for tape and woven, respectively). Prior to RDS testing, all specimens were dried in a vacuum oven for 5 days at 160°F. The results of these RDS Tg tests are summarized in Table 6. As seen by the Tg data, the current moisture conditioning procedure does not significantly degrade the LTM25 resin.

6.0 Test Procedures

6.1 Longitudinal and Transverse Tension

The procedure used conforms to ASTM D3039, "Standard Test Method for Tensile Properties of Fiber-Resin Composites." The tension specimens were strain gaged with one biaxial strain gage as shown in Figures 8 and 9 for the longitudinal and transverse specimens, respectively. All strain gages were adhesively bonded to the specimen using M-Bond 200 adhesive and cured at room temperature.

Each specimen was placed in the hydraulic grips of a tension test frame. The temperature on the surface of the -125°F and 180°F specimens was held for 10 minutes prior to testing. All specimens were loaded in tension at a rate of 0.05 inch/minute until failure. The maximum load, stress, modulus, Poisson's ratio, and strain to failure was reported.

6.2 Longitudinal and Transverse Compression Strength

This procedure conforms to ASTM D695, "Compressive Properties of Rigid Plastics." Each specimen was mounted in a suitable fixture which conforms to ASTM D695. The temperature on the surface of the -125°F and 180°F specimens was held for 10 minutes prior to testing. All specimens were loaded in compression at a rate of 0.05 inch/minute until failure. The maximum load and stress was reported. The strain to failure was calculated by dividing the actual stress by the actual modulus recorded from Section 6.3.

6.3 Longitudinal and Transverse Compression Modulus

This procedure conforms to ASTM D695, "Compressive Properties of Rigid Plastics." Each specimen was mounted in a suitable fixture which conforms to ASTM D695. The specimens were strain gaged with two back-to-back biaxial strain gages as shown in Figure 11. All strain gages were adhesively bonded to the specimen using M-Bond 200 adhesive and cured at room temperature.

Each specimen was mounted in a suitable fixture which conforms to ASTM D695. The temperature on the surface of the -125°F and 180°F specimens was held for 10 minutes prior to testing. All specimens were loaded in compression at a rate of 0.05 inch/minute to failure. Since this specimen is unsupported, the ultimate load and strength values are not valid. The modulus and Poisson's ratio was reported from the linear portion of the stress-strain curve for each specimen.

It should be noted that Poisson's ratio values are not generally reported for compression tests. Small transverse compression strains make calculating Poisson's ratio extremely difficult and inaccurate.

6.4 Transverse Compression For Tape Specimens Only.

This procedure conforms to the Northrop Grumman specification for 3-inch by 1-inch compression specimen testing. All specimens were strain gaged with two back-to-back biaxial strain gages as shown in Figure 12. All strain gages were adhesively bonded to the specimen using M-Bond 200 adhesive and cured at room temperature.

Each specimen was placed in a Northrop Grumman 3-inch by 1-inch compression buckling fixture. The temperature on the surface of the -125°F and 180°F specimens was held for 10 minutes prior to testing. All specimens were loaded in compression at a rate of 0.05 inch/minute until failure. The maximum load, stress, modulus, Poisson's ratio, and strain to failure were reported for all specimens. The modulus and Poisson's ratio was reported from the linear portion of the stress-strain curve.

It should be noted that Poisson's ratio values are not generally reported for compression tests. Small transverse compression strains make calculating Poisson's ratio extremely difficult and inaccurate.

6.5 In-Plane Shear

This test procedure conforms to ASTM D3518, "Standard Recommended Practice for In-Plane Shear Stress-Strain Response of Unidirectional Reinforced Plastics." All specimens were strain gaged with one biaxial strain gage as shown in Figure 13. All strain gages were adhesively bonded to the specimen using M-Bond 200 adhesive and cured at room temperature.

All specimens were placed in the hydraulic grips of tension test frame. The temperature on the surface of the -125°F and 180°F specimens was held for 10 minutes prior to testing. Each specimen was loaded in tension at a rate of 0.05 inch/minute until failure. The maximum load, shear stress, shear modulus, and shear strain to failure was reported for all in-plane shear specimens. The shear modulus was reported from the linear portion of the shear stress-shear strain curve.

6.6 Rheometric Dynamic Spectroscopy (RDS)

RDS testing was conducted according to the Northrop Grumman B2 Division process specification T-139A. Torsional rectangular RDS tests were performed at a strain of 0.01 percent, frequency = 10 rads/second, and a measurement interval of 0.5 minutes. Each specimen was purged with nitrogen at a flow rate of 5 ft³/minute prior to testing. All specimens were scanned at 18°F/minute from 70°F to 570°F.

The G' (storage modulus), G" (loss modulus), and Tan Delta versus temperature were plotted over the entire temperature range. TΔG' was reported as the Tg of the specimen by drawing two tangents to the linear portions of the G' curve. The Tg, measured in degrees Celsius, was marked by the intersection point of the two tangents. The average of three specimens was reported as the Tg for a particular product form and environmental condition.

6.7 Coefficient of Thermal Expansion (CTE)

The CTE was measured using a dilatronic instrument. The dilatronic instrument simultaneously compares the expansion of a known reference material (silica) to the expansion of the sample. CTE measurements were made from -125°F to 180°F at a ramp rate of 9°F/minute. The average CTE at room temperature from three specimens was reported for the longitudinal and transverse orientations of both product forms.

6.8 Resin Content

The resin content (weight percent), fiber volume fraction (volume percent), void content (volume percent), and density were determined using the acid digestion method. Three specimens were evaluated for each laminate tested.

6.9 Property Normalization

Normalization of some properties was conducted with respect to the measured ply thickness of each product form. The per-ply thickness was determined by averaging all the specimen thicknesses tested for this program for each product form. The per-ply thicknesses were calculated to be 0.00576 inch and 0.00904 inch for MR50/LTM25 and CFS003/LTM25, respectively. These values were used to normalize some of the mechanical properties as follows:

$$\text{Normalized value} = (\text{Actual value}) \times (\text{specimen thickness} / \text{nominal thickness})$$

7.0 Test Results

7.1 Mechanical Properties

A detailed summary of the mechanical properties is shown in Tables 7 through 20. These tables show the results for individual tests, failure mode, any test anomalies, and physical properties of the associated laminate from which the specimens were machined. Generally, the results for both product forms are very consistent. The strain to failure for some of the transverse compression tape, longitudinal tension tape, and longitudinal and transverse tension woven specimens were calculated by dividing the actual stress by the actual modulus. Strain gage data were not available for these specimens because of premature gage failures. Similarly, shear strain was calculated by dividing the actual shear stress by

the actual shear modulus because the specimens exceeded the maximum strain range of the gage (50,000 μ in/in).

Poisson's ratio, for many specimens, was not reported because either the value of the transverse strain was extremely small, or the strain gages failed prematurely. In one case, the transverse strain for a transverse compression test was negative, thus invalidating the Poisson's ratio value. These circumstances explain the high coefficient of variation values observed for some of the tests.

The open-hole tension data presented in Table 18 was generated to support further evaluation of these materials at NASA Langley Research Center. Specimens used to generate the data in Table 18 were not dried as described in section 5.0, but instead were tested at -125 °F ambient condition as-fabricated.

A condensed version of the mechanical properties is shown in Tables 21 through 26 and Tables 27 through 32 for the tape and woven product forms, respectively. These tables display only the requested design data from the original statement of work. It should be noted that not all the values shown in these tables are derived from six specimens.

7.2 RDS Results

The results for the RDS testing is shown in Table 33. The ambient Tg for both the tape and woven materials are about 265°F which is expected since all laminates were post cured at 250°F for two hours. Moisture content seemed to lower the Tg for both materials by about 45°F.

7.3 CTE Results

The results for the CTE testing are shown in Table 34. The longitudinal CTE value for tape is negative because the test is essentially measuring the expansion of graphite fiber which itself is slightly negative. The transverse CTE value for tape is significantly higher than the longitudinal value. The reason is because the expansion of the LTM25 resin, measured by the transverse test, is higher than the graphite fiber. Both longitudinal and transverse CTE values for the woven material are essentially equivalent which is expected for plain weave woven composites.

7.4 Physical Results

The results for the physical testing are shown in Table 35. The tape laminates all fall within the acceptable required values for resin content and fiber volume fraction (RC 29% and FV 63%). The resin content of the woven panels, however, was typically higher than the required value of 41%. Similarly, the fiber content of the woven panels was slightly lower than the required value of 50%. No manufacturing anomalies were identified to explain this minor discrepancy with the woven physical results.

Table 1. Mechanical Properties Requested By NASA.

Property	Description	Units
E^t_1	Longitudinal modulus, tension	Msi
E^c_1	Longitudinal modulus, compression	Msi
E^t_2	Transverse modulus, tension	Msi
E^c_2	Transverse modulus, compression	Msi
G_{12}^s	In-plane shear modulus	Msi
ν_{12}^t	Major Poisson's ratio, tension	--
ν_{12}^c	Major Poisson's ratio, compression	--
F_1^{tu}	Longitudinal ultimate stress, tension	ksi
F_1^{cu}	Longitudinal ultimate stress, compression	ksi
F_2^{tu}	Transverse ultimate stress, tension	ksi
F_2^{cu}	Transverse ultimate stress, compression	ksi
F_{12}^{su}	In-plane shear ultimate stress	ksi
ϵ_1^{tu}	Longitudinal ultimate strain, tension	μ in/in
ϵ_1^{cu}	Longitudinal ultimate strain, compression	μ in/in
ϵ_2^{tu}	Transverse ultimate strain, tension	μ in/in
ϵ_2^{cu}	Transverse ultimate strain, compression	μ in/in
γ_{12}^{su}	In-plane shear ultimate strain	μ in/in

Table 2. Additional Properties Requested By NASA.

Property	Description	Units
M_g	Moisture weight gain from the as-fabricated condition to the saturated condition	%
t_{nom}	Nominal ply thickness	inch
T_g	Glass transition temperature as-fabricated	°F
T_g	Glass transition temperature after reaching saturation during moisture conditioning	°F
V_f	Fiber volume fraction	%
α_1	Longitudinal coefficient of thermal expansion at room temperature	(in/in/°F)
α_2	Transverse coefficient of thermal expansion at room temperature	(in/in/°F)
ρ	Laminate density	lb/in ³

Table 3. Test Matrix for LTM25 Mechanical Property Evaluation.

Mechanical Test	Product Form	Test Method	Design Data	Test Conditions		
				-125°F/Dry	RTD	180°F/Wet
Longitudinal Tension	Tape Woven	ASTM D3039	E ₁ , F ₁ , e ₁ , v ₁₂	6	6	6
Transverse Tension	Tape Woven	ASTM D3039	E ₂ , F ₂ , e ₂ , v ₂₁	6	6	6
Longitudinal Compression	Tape Woven	ASTM D695	F ₁	6	6	6
			E ₁ , e ₁ , v ₁₂	6	6	6
Transverse Compression	Tape	Northrop 3x1	E ₂ , F ₂ , e ₂ , v ₂₁	6	6	6
	Woven	ASTM D695	F ₂	6	6	6
			E ₂ , e ₂ , v ₂₁	6	6	6
In-Plane Shear	Tape Woven	ASTM D3518	G ₁₂ , F ₁₂ , y ₁₂	6	6	6

Table 4. Description of Panels Shipped to NASA.

Panel Number	Material	Dimensions (inches)	Layup *	Number of Plies	Debulk Procedure
7	MR50/LTM25 Tape	28 x 12	[45/0/-45/90]6S	48	Every four plies for 15 min.
8	MR50/LTM25 Tape	28 x 12	[45/0/-45/90]6S	48	Every four plies for 15 min.
9	MR50/LTM25 Tape	28 x 12	[45/0/-45/90]2S	16	Every four plies for 15 min.
10	CFS003/LTM25 Woven	28 x 12	[45/0/-45/90]4S	32	Every four plies for 15 min.
11	CFS003/LTM25 Woven	28 x 12	[45/0/-45/90]4S	32	Every four plies for 15 min.
12	CFS003/LTM25 Woven	28 x 12	[45/0/-45/90]2S	16	Every four plies for 15 min.
13	MR50/LTM25 Tape	12 x 12	[0]24	24	Every four plies for 15 min.
14	MR50/LTM25 Tape	12 x 12	[0]24	24	Every 24 plies for one hour.
15	MR50/LTM25 Tape	12 x 12	[(0/90)6]S	24	Every four plies for 15 min.
16	MR50/LTM25 Tape	12 x 12	[(0/90)6]S	24	Every 24 plies for one hour.
17	CFS003/LTM25 Woven	12 x 12	[0]24	24	Every four plies for 15 min.
18	CFS003/LTM25 Woven	12 x 12	[0]24	24	Every 24 plies for one hour.

* The 0° direction is parallel to the long edge of the panels.

Table 5. Summary of Ultrasonic Inspection Results.

Panel Number	ASDL Number	Material	Dimensions (inches)	Average dB Loss
1	9914	Tape ¹	22.5 x 18	5.0
2	9915	Tape ¹	16 x 10.5	8.6
3	9916	Tape ¹	22 x 16.5	14.8
4	9917	Tape ¹	17 x 14	16.5
5	9918	Woven ²	28 x 25	5.9
6	9919	Woven ²	20 x 16.5	13.9
7	9920	Tape ¹	28 x 12	13.2
8	9921	Tape ¹	28 x 12	15.1
9	9922	Tape ¹	28 x 12	7.7
10	9923	Woven ²	28 x 12	16.5
11	9924	Woven ²	28 x 12	18.8
12	9925	Woven ²	28 x 12	9.9
13	9926	Tape ¹	12 x 12	8.5
14	9927	Tape ¹	12 x 12	9.0
15	9928	Tape ¹	12 x 12	9.3
16	9929	Tape ¹	12 x 12	9.3
17	9930	Woven ²	12 x 12	15.8
18	9931	Woven ²	12 x 12	14.8

Notes 1. MR50/LTM25 Unidirectional Tape, Batch 588cu
 2. CFS003/LTM25 Woven Cloth, Batch 1661

Table 6. Summary of RDS Tg Data for Environmentally Conditioned Specimens.

Environmental Condition	Tg (°F)	
	Tape	Woven
Dry	259	258
Moisture Condition Followed by drying	242	245

Table 7. Longitudinal Compression Modulus Results for MR50/LTM25 Unidirectional Tape.

SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER PLY THICKNESS (inch)	LONGITUDINAL MODULUS		MPLR 35325 POISSONS RATIO
					ACTUAL (Msi)	NORMALIZED (1) (Msi)	
TZDCM-01	-125°F/DRY	0.499	0.055	0.00550	23.40	22.34	0.347
TZDCM-02		0.500	0.053	0.00530	21.75	20.01	0.358
TZDCM-03		0.500	0.055	0.00550	20.97	20.03	0.422
TZDCM-04		0.499	0.055	0.00550	22.30	21.29	0.344
TZDCM-05		0.500	0.055	0.00550	21.70	20.72	0.349
TZDCM-06		0.499	0.054	0.00540	23.02	21.58	0.363
		AVERAGE: Minimum Maximum C.V., %:	0.500 0.499 0.500 0.11	0.00545 0.00530 0.00550 1.54	22.19 20.97 23.40 4.07	20.99 20.01 22.34 4.38	0.364 0.344 0.422 8.07
TZDCM-07	RTD	0.500	0.057	0.00570	21.32	21.09	0.330
TZDCM-08		0.500	0.057	0.00570	21.67	21.44	0.374
TZDCM-09		0.500	0.057	0.00570	21.99	21.76	0.395
TZDCM-10		0.500	0.054	0.00540	23.57	22.10	0.393
TZDCM-11		0.500	0.057	0.00570	21.56	21.33	0.360
TZDCM-12		0.500	0.055	0.00550	23.56	22.49	0.345
		AVERAGE: Minimum Maximum C.V., %:	0.500 0.500 0.500 0.00	0.00562 0.00540 0.00570 2.37	22.28 21.32 23.57 4.58	21.70 21.09 22.49 2.40	0.366 0.330 0.395 7.13
TZDCM-13	180°F/WET	0.500	0.058	0.00580	21.41	21.56	0.402
TZDCM-14		0.500	0.057	0.00570	22.23	22.00	0.415
TZDCM-15		0.500	0.056	0.00560	22.29	21.67	0.361
TZDCM-16		0.500	0.054	0.00540	23.77	22.29	0.446
TZDCM-17		0.500	0.055	0.00550	22.05	21.05	0.520
TZDCM-18		0.500	0.057	0.00570	22.07	21.84	0.445
		AVERAGE: Minimum Maximum C.V., %:	0.500 0.500 0.500 0.00	0.00562 0.00540 0.00580 2.62	22.30 21.41 23.77 3.52	21.74 21.05 22.29 1.94	0.431 0.361 0.520 12.39

- NOTES: 1. Normalized stress is calculated using a nominal ply thickness of 0.00576 inch.
 2. Specimens were tested for modulus.
 3. Specimens had a laminate orientation of [0_n] with a nominal laminate thickness of 0.0576 inch.
 4. Wet specimens were moisture conditioned to an equilibrium moisture content of 0.77%.
 5. Laminate 9914 had a delta dB loss of 5.0.
 6. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9914	29.50	61.41	1.77	0.055

Table 8. Longitudinal Compression Strength Results for MR50/LTM25 Unidirectional Tape.

SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)	FAILURE STRESS		STRAIN TO FAILURE (3) (μin/in)	FAILURE MODE (2)	
						ACTUAL (ksi)	NORMALIZED (1) (ksi)			
TZDCS-01	-125°F/DRY	0.499	0.054	0.00540	5810	215.62	202.14	9717	(a)	
TZDCS-02		0.499	0.055	0.00550	5880	214.25	204.58	9656	(b)	
TZDCS-03		0.499	0.055	0.00550	6480	236.11	225.45	10641	(a)	
TZDCS-04		0.499	0.055	0.00550	5880	214.25	204.58	9656	(b)	
TZDCS-05		0.499	0.056	0.00560	5450	195.03	189.62	8790	(b)	
TZDCS-06		0.499	0.054	0.00540	5970	221.55	207.71	9985	(a)	
		AVERAGE:	0.499	0.055	0.00548	5912	216.13	205.68	9741	
		Minimum	0.499	0.054	0.00540	5450	195.03	189.62	8790	
		Maximum	0.499	0.056	0.00560	6480	236.11	225.45	10641	
		C.V., %:	0.00	1.37	1.37	5.62	6.14	5.62	6.14	
TZDCS-07	RTD	0.498	0.054	0.00540	5260	195.60	183.37	8780	(b)	
TZDCS-08		0.499	0.056	0.00560	4800	171.77	167.00	7711	(b)	
TZDCS-09		0.499	0.056	0.00560	4720	168.91	164.22	7582	(b)	
TZDCS-10		0.499	0.056	0.00560	4150	148.51	144.39	6667	(a)	
TZDCS-11		0.499	0.055	0.00550	4750	173.07	165.26	7769	(b)	
TZDCS-12		0.499	0.057	0.00570	4700	165.24	163.52	7418	(b)	
		AVERAGE:	0.499	0.056	0.00557	4730	170.52	164.63	7655	
		Minimum	0.498	0.054	0.00540	4150	148.51	144.39	6667	
		Maximum	0.499	0.057	0.00570	5260	195.60	183.37	8780	
		C.V., %:	0.08	1.86	1.86	7.47	8.90	7.53	8.90	
TZDCS-13	180°F/WET	0.501	0.054	0.00540	3000	110.89	103.96	4972	(a)	
TZDCS-14		0.501	0.055	0.00550	3400	123.39	117.82	5532	(a)	
TZDCS-15		0.501	0.054	0.00540	2940	108.67	101.88	4872	(a)	
TZDCS-16		0.501	0.055	0.00550	3230	117.22	111.93	5256	(a)	
TZDCS-17		0.501	0.055	0.00550	2590	93.99	89.75	4214	(a)	
TZDCS-18		0.501	0.053	0.00530	3340	125.79	115.74	5640	(a)	
		AVERAGE:	0.501	0.054	0.00543	3083	113.33	106.85	5081	
		Minimum	0.501	0.053	0.00530	2590	93.99	89.75	4214	
		Maximum	0.501	0.055	0.00550	3400	125.79	117.82	5640	
		C.V., %:	0.00	1.50	1.50	9.82	10.24	9.82	10.24	

- NOTES: 1. Normalized stress is calculated using a nominal ply thickness of 0.00576 inch.
 2. Failure modes:
 (a) Compression failure in gage section.
 (b) Broom failure at bottom edge.
 3. Strain to failure was calculated by dividing the actual strength obtained from the tests above by the average modulus listed in Table 7.
 4. Specimens had a laminate orientation of [0₁₀] with a nominal laminate thickness of 0.0576 inch.
 5. Wet specimens were moisture conditioned to an equilibrium moisture content of 1.13%.
 6. Laminate 9914 had a delta dB loss of 5.0.
 7. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9914	29.50	61.41	1.77	0.055

Table 9. Transverse Compression Results for MR50/LTM25 Unidirectional Tape.

MPLR 35325										
SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)	FAILURE STRENGTH (ksi)	STRAIN TO FAILURE (μin/in)	TRANSVERSE MODULUS (Ms)	POISSON'S RATIO (3)	FAILURE MODE (2)
TNDC-01	-125°F/DRY	1.000	0.136	0.00567	4860	35.74	25774	1.39	0.024	(b)
TNDC-02		1.000	0.136	0.00567	4900	36.03	22949	1.57	0.032	(b)
TNDC-03		1.000	0.136	0.00567	4820	35.44	18478	1.92	0.024	(b)
TNDC-04		1.000	0.135	0.00563	4320	32.00	20019	1.60	0.024	(b)
TNDC-05		1.000	0.136	0.00567	5000	36.76	27203	1.35	0.035	(b)
TNDC-06		1.000	0.136	0.00567	4350	31.99	21366	1.50	0.033	(b)
		AVERAGE:	1.000	0.136	0.00566	4708	34.66	22631	1.55	0.029
		Minimum	1.000	0.135	0.00563	4320	31.99	18478	1.35	0.024
		Maximum	1.000	0.136	0.00567	5000	36.76	27203	1.92	0.035
		C.V., %:	0.00	0.30	0.30	6.28	6.09	14.86	13.10	18.15
TNDC-07	RTD	1.000	0.136	0.00567	2930	21.54	28337	1.15	0.011	(a)
TNDC-08		1.000	0.134	0.00558	2680	20.00	25961	1.10	0.013	(a)
TNDC-09		1.000	0.136	0.00567	2920	21.47	25826	1.30		(a)
TNDC-10		1.000	0.135	0.00563	2740	20.30	24803	1.14	0.011	(a)
TNDC-11		1.000	0.136	0.00567	3000	22.06	22739	1.22	0.010	(a)
TNDC-12		1.000	0.135	0.00563	2850	21.11	23434	1.35		(a)
		AVERAGE:	1.000	0.135	0.00564	2853	21.08	25183	1.21	0.011
		Minimum	1.000	0.134	0.00558	2680	20.00	22739	1.10	0.010
		Maximum	1.000	0.136	0.00567	3000	22.06	28337	1.35	0.013
		C.V., %:	0.00	0.60	0.60	4.28	3.74	7.97	7.90	11.18
TNDC-13	180°F/WET	1.000	0.135	0.00563	1490	11.04	21519	1.09	0.007	(a)
TNDSPA-01		1.000	0.135	0.00563	1530	11.33	25701	1.02		(a)
TNDC-15		1.000	0.136	0.00567	1420	10.44		0.86	0.023	(b)
TNDSPA-02		1.000	0.135	0.00563	1610	11.93	27691	1.04	0.010	(a)
TNDC-17		1.000	0.136	0.00567	1360	10.00	28343	0.89	0.010	(a)
TNDSPA-03		1.000	0.135	0.00563	1330	9.85	23067	0.85	0.008	(a)
		AVERAGE:	1.000	0.135	0.00564	1457	10.76	25264	0.96	0.012
		Minimum	1.000	0.135	0.00563	1330	9.85	21519	0.85	0.007
		Maximum	1.000	0.136	0.00567	1610	11.93	28343	1.09	0.023
		C.V., %:	0.00	0.38	0.38	7.31	7.51	11.61	10.55	56.07

NOTES: 1. Failure strength and transverse modulus were not normalised since they were deemed to be resin properties.

2. Failure modes:

- (a) Compression failure in gage section.
- (b) Compression failure in gage section. Strain gage failed prior to specimen failure: strains were calculated from the actual strength and modulus.

3. Poisson's ratio was not reported for specimens that had negative transverse strain values.

4. Specimens had a laminate orientation of [90₂₄] with a nominal laminate thickness of 0.138 inch.

5. Wet specimens were moisture conditioned to an equilibrium moisture content of 0.73%.

6. Laminate 9915 had a delta dB loss of 8.6.

7. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9915	27.97	62.85	2.190	0.055

Table 10. Longitudinal Compression Modulus Results for CFS003/LTM25 Woven Cloth.

SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER PLY THICKNESS (inch)	LONGITUDINAL MODULUS		MPLR 35328 POISSON'S RATIO (2)	
					ACTUAL (Msi)	NORMALIZED (1) (Msi)		
WZDCM-01	-125°F/DRY	0.500	0.068	0.00850	7.14	6.72	0.066	
WZDCM-02		0.500	0.068	0.00850	8.06	7.58	0.087	
WZDCM-03		0.500	0.068	0.00850	8.74	8.22	0.100	
WZDCM-04		0.500	0.070	0.00875	6.66	6.45	0.074	
WZDCM-05		0.500	0.069	0.00863	7.02	6.70	0.050	
WZDCM-06		0.500	0.069	0.00863	7.15	6.82	0.079	
		AVERAGE:	0.500	0.069	0.00858	7.46	7.08	0.076
		Minimum	0.500	0.068	0.00850	6.66	6.45	0.050
		Maximum	0.500	0.070	0.00875	8.74	8.22	0.100
		C.V., %:	0.00	1.19	1.19	10.45	9.58	22.68
WZDCM-07	RTD	0.500	0.068	0.00850	6.69	6.29	0.024	
WZDCM-08		0.500	0.069	0.00863	7.26	6.93		
WZDCM-09		0.500	0.068	0.00850	7.35	6.91	0.041	
WZDCM-10		0.500	0.069	0.00863	6.77	6.46	0.012	
WZDCM-11		0.500	0.069	0.00863	7.34	7.00	0.079	
WZDCM-12		0.500	0.069	0.00863	7.81	7.45	0.011	
		AVERAGE:	0.500	0.069	0.00858	7.20	6.84	0.033
		Minimum	0.500	0.068	0.00850	6.69	6.29	0.011
		Maximum	0.500	0.069	0.00863	7.81	7.45	0.079
		C.V., %:	0.00	0.75	0.75	5.74	6.04	84.49
WZDCM-13	180°F/WET	0.500	0.070	0.00875	8.09	7.83	0.076	
WZDCM-14		0.500	0.068	0.00850	8.32	7.83		
WZDCM-15		0.500	0.069	0.00863	8.17	7.79	0.073	
WZDCM-16		0.500	0.069	0.00863	7.85	7.49	0.014	
WZDCM-17		0.500	0.068	0.00850	8.51	8.00	0.035	
WZDCM-18		0.500	0.069	0.00863	9.28	8.85	0.058	
		AVERAGE:	0.500	0.069	0.00860	8.37	7.97	0.051
		Minimum	0.500	0.068	0.00850	7.85	7.49	0.014
		Maximum	0.500	0.070	0.00875	9.28	8.85	0.076
		C.V., %:	0.00	1.09	1.09	5.94	5.84	51.52

- NOTES: 1. Normalized stress is calculated using a nominal ply thickness of 0.00904 inch.
 2. Poisson's ratio for specimens WZDCM-8 and -14 were not determined because of negative transverse strains.
 3. Specimens were tested for modulus only.
 4. Specimens had a laminate orientation of [0₆] with a nominal laminate thickness of 0.0723 inch.
 5. Wet specimens were moisture conditioned to an equilibrium moisture content of 1.02%.
 6. Laminate 9918 had a delta dB loss of 5.9.
 7. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9918	42.74	47.80	1.27	0.053

Table 11. Longitudinal Compression Strength Results for CFS003/LTM25 Woven Cloth.

MPLR 35328

SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN	SPECIMEN	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)	FAILURE STRESS		STRAIN TO FAILURE (3) ($\mu\text{in/in}$)	FAILURE MODE (2)
		WIDTH (inch)	THICKNESS (inch)			ACTUAL (ksi)	NORMALIZED (1) (ksi)		
WZDCS-01	-125°F/DRY	0.499	0.072	0.00900	4160	115.79	115.31	15515	(a)
WZDCS-02		0.499	0.073	0.00913	3985	109.40	110.46	14659	(a)
WZDCS-03		0.499	0.073	0.00913	4110	112.83	113.92	15118	(a)
WZDCS-04		0.499	0.072	0.00900	4155	115.65	115.17	15496	(a)
WZDCS-05		0.499	0.072	0.00900	3890	108.27	107.82	14508	(a)
WZDCS-06		0.499	0.072	0.00900	4160	115.79	115.31	15515	(a)
	AVERAGE:	0.499	0.072	0.00904	4077	112.95	113.00	15135	
	Minimum	0.499	0.072	0.00900	3890	108.27	107.82	14508	
	Maximum	0.499	0.073	0.00913	4160	115.79	115.31	15515	
	C.V., %:	0.00	0.71	0.71	2.78	3.01	2.78	3.01	
WZDCS-07	RTD	0.499	0.072	0.00900	3525	98.11	97.71	13622	(a)
WZDCS-08		0.499	0.073	0.00913	3360	92.24	93.13	12806	(a)
WZDCS-09		0.499	0.073	0.00913	3260	89.49	90.36	12425	(a)
WZDCS-10		0.499	0.072	0.00900	3350	93.24	92.86	12945	(a)
WZDCS-11		0.499	0.072	0.00900	3240	90.18	89.81	12520	(a)
WZDCS-12		0.499	0.072	0.00900	3430	95.47	95.07	13255	(a)
	AVERAGE:	0.499	0.072	0.00904	3361	93.12	93.16	12929	
	Minimum	0.499	0.072	0.00900	3240	89.49	89.81	12425	
	Maximum	0.499	0.073	0.00913	3525	98.11	97.71	13622	
	C.V., %:	0.00	0.71	0.71	3.17	3.50	3.17	3.50	
WZDCS-13	180°F/WET	0.501	0.072	0.00900	1940	53.78	53.56	6427	(a)
WZDCS-14		0.501	0.072	0.00900	1980	54.89	54.66	6559	(a)
WZDCS-15		0.501	0.071	0.00888	2125	59.74	58.67	7139	(a)
WZDCS-16		0.501	0.071	0.00888	1885	52.99	52.04	6333	(a)
WZDCS-17		0.500	0.071	0.00888	1740	49.01	48.13	5857	(a)
WZDCS-18		0.500	0.071	0.00888	2130	60.00	58.92	7170	(a)
	AVERAGE:	0.501	0.071	0.00892	1967	55.07	54.33	6581	
	Minimum	0.500	0.071	0.00888	1740	49.01	48.13	5857	
	Maximum	0.501	0.072	0.00900	2130	60.00	58.92	7170	
	C.V., %:	0.10	0.72	0.72	7.57	7.65	7.55	7.65	

NOTES: 1. Normalized stress is calculated using a nominal ply thickness of 0.00904 inch.

2. Failure modes:

(a) Compression failure in gage section.

3. Strain to failure was calculated by dividing the actual strength obtained from the tests above by the average modulus listed in Table 10.

4. Specimens had a laminate orientation of [0₈] with a nominal laminate thickness of 0.0723 inch.

5. Wet specimens were moisture conditioned to an equilibrium moisture content of 1.14%.

6. Laminate 9918 had a delta dB loss of 5.9.

7. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9918	42.74	47.80	1.27	0.053

Table 12. Transverse Compression Modulus Results for CFS003/LTM25 Woven Cloth.

SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN	SPECIMEN	PER-PLY	LONGITUDINAL MODULUS		POISSONS RATIO (2)
		WIDTH (inch)	THICKNESS (inch)	THICKNESS (inch)	ACTUAL (Msi)	NORMALIZED (1) (Msi)	
WNDCM-01	-125°F/DRY	0.500	0.068	0.00850	8.10	7.62	0.069
WNDCM-02		0.500	0.067	0.00838	7.92	7.34	0.078
WNDCM-03		0.500	0.068	0.00850	7.43	6.99	0.060
WNDCM-04		0.500	0.068	0.00850	7.54	7.09	0.060
WNDCM-05		0.500	0.068	0.00850	7.94	7.46	0.068
WNDCM-06		0.500	0.067	0.00838	8.10	7.51	0.073
		AVERAGE:	0.500	0.068	0.00846	7.84	
		Minimum	0.500	0.067	0.00838	7.43	0.068
		Maximum	0.500	0.068	0.00850	8.10	0.060
		C.V., %:	0.00	0.76	0.76	3.63	0.078
							10.48
WNDCM-07	RTD	0.500	0.067	0.00838	7.60	7.04	
WNDCM-08		0.500	0.067	0.00838	7.60	7.04	
WNDCM-09		0.500	0.069	0.00863	7.54	7.20	
WNDCM-10		0.500	0.068	0.00850	7.43	6.98	0.031
WNDCM-11		0.500	0.067	0.00838	7.67	7.10	0.063
WNDCM-12		0.500	0.068	0.00850	7.39	6.95	0.011
		AVERAGE:	0.500	0.068	0.00846	7.54	
		Minimum	0.500	0.067	0.00838	7.39	0.035
		Maximum	0.500	0.069	0.00863	7.67	0.011
		C.V., %:	0.00	1.21	1.21	1.44	0.063
							74.94
WNDCM-13	180°F/WET	0.500	0.068	0.00850	7.13	6.71	
WNDCM-14		0.500	0.068	0.00850	7.17	6.74	
WNDCM-15		0.500	0.067	0.00838	7.05	6.53	
WNDCM-16		0.500	0.068	0.00850	6.96	6.54	
WNDCM-17		0.500	0.068	0.00850	7.38	6.94	0.029
WNDCM-18		0.500	0.068	0.00850	7.63	7.18	0.017
		AVERAGE:	0.500	0.068	0.00848	7.22	
		Minimum	0.500	0.067	0.00838	6.96	0.023
		Maximum	0.500	0.068	0.00850	7.63	0.017
		C.V., %:	0.00	0.60	0.60	3.39	0.029
							36.89

- NOTES:**
- Normalized stress is calculated using a nominal ply thickness of 0.00904 inch.
 - Poisson's ratio for specimens WNDCM-7,8,9 and 13,14,15, and 16 were not determined because of negative transverse strains.
 - Specimens were tested for modulus only and were not taken to failure.
 - Specimens had a laminate orientation of [0₈] with a nominal laminate thickness of 0.0723 inch.
 - Wet specimens were moisture conditioned to an equilibrium moisture content of 0.99%.
 - Laminate 9918 had a delta dB loss of 5.9.
 - Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9918	42.74	47.80	1.27	0.053

Table 13. Transverse Compression Strength Results for CFS003/LTM25 Woven Cloth.

MPLR 35328

SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)	FAILURE STRESS		STRAIN TO FAILURE (3) ($\mu\text{in/in}$)	FAILURE MODE (2)	
						ACTUAL (ksi)	NORMALIZED (1) (ksi)			
WNDCS-01	-125°F/DRY	0.500	0.070	0.00875	3265	93.29	90.32	11901	(a)	
WNDCS-02		0.500	0.071	0.00888	3525	99.30	97.51	12667	(a)	
WNDCS-03		0.500	0.070	0.00875	3510	100.29	97.10	12794	(a)	
WNDCS-04		0.500	0.071	0.00888	3535	99.58	97.79	12703	(a)	
WNDCS-05		0.500	0.072	0.00900	3790	105.28	104.84	13430	(a)	
WNDCS-06		0.500	0.072	0.00900	3780	105.00	104.56	13395	(a)	
		AVERAGE:	0.500	0.071	0.00888	3568	100.45	98.69	12815	
		Minimum	0.500	0.070	0.00875	3265	93.29	90.32	11901	
		Maximum	0.500	0.072	0.00900	3790	105.28	104.84	13430	
		C.V., %:	0.00	1.26	1.26	5.50	4.39	5.50	4.39	
WNDCS-07	RTD	0.500	0.071	0.00888	2850	80.28	78.84	10652	(a)	
WNDCS-08		0.500	0.071	0.00888	2835	79.86	78.42	10596	(a)	
WNDCS-09		0.500	0.072	0.00900	3175	88.19	87.83	11702	(a)	
WNDCS-10		0.500	0.072	0.00900	3250	90.28	89.90	11978	(a)	
WNDCS-11		0.500	0.071	0.00888	2750	77.46	76.07	10278	(a)	
WNDCS-12		0.500	0.071	0.00888	2630	74.08	72.75	9830	(a)	
		AVERAGE:	0.500	0.071	0.00892	2915	81.69	80.64	10839	
		Minimum	0.500	0.071	0.00888	2630	74.08	72.75	9830	
		Maximum	0.500	0.072	0.00900	3250	90.28	89.90	11978	
		C.V., %:	0.00	0.72	0.72	8.39	7.69	8.39	7.69	
WNDCS-13	180°F/WET	0.501	0.069	0.00863	1810	52.36	49.97	7253	(a)	
WNDCS-14		0.501	0.070	0.00875	1875	53.46	51.76	7406	(a)	
WNDCS-15		0.501	0.070	0.00875	1815	51.75	50.11	7169	(a)	
WNDCS-16		0.501	0.069	0.00863	2075	60.02	57.29	8315	(a)	
WNDCS-17		0.501	0.070	0.00875	1960	55.89	54.11	7742	(a)	
WNDCS-18		0.501	0.070	0.00875	1780	50.76	49.14	7031	(a)	
		AVERAGE:	0.501	0.070	0.00871	1886	54.04	52.06	7486	
		Minimum	0.501	0.069	0.00863	1780	50.76	49.14	7031	
		Maximum	0.501	0.070	0.00875	2075	60.02	57.29	8315	
		C.V., %:	0.00	0.74	0.74	5.97	6.32	5.97	6.32	

NOTES: 1. Normalized stress is calculated using a nominal ply thickness of 0.00904 inch.

2. Failure modes:

(a) Compression failure in gage section.

3. Strain to failure was calculated by dividing the actual strength obtained from the tests above by the average modulus listed in Table 12.

4. Specimens had a laminate orientation of [0₆] with a nominal laminate thickness of 0.0723 inch.

5. Wet specimens were moisture conditioned to an equilibrium moisture content of 1.14%.

6. Laminate 9918 had a delta dB loss of 5.9.

7. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9918	42.74	47.80	1.27	0.053

Table 14. Longitudinal Tension Results for MRS0/LTM25 Unidirectional Tape.

MPLR 36325										
SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY FAILURE LOAD (pounds)	FAILURE STRESS		STRAIN TO FAILURE (in/in)	LONGITUDINAL MODULUS		FAILURE MODE (2)
					ACTUAL (ksi)	NORMALIZED (1) (ksi)		ACTUAL (Msi)	NORMALIZED (1) (Msi)	
TZDT-01		0.498	0.058	0.00580	8250	285.63	287.61	11953	20.28	0.335 (a)
TZDT-02		0.500	0.058	0.00580	7250	250.00	251.74	10735	20.33	0.335 (a)
TZDT-03	-125°F/DRY	0.499	0.058	0.00580	8980	310.28	312.43	12613	21.35	0.463 (a)
TZDT-04		0.499	0.058	0.00580	7880	272.27	274.16	11635	20.06	0.352 (a)
TZDT-05		0.499	0.060	0.00600	8200	273.88	285.29	11780	20.06	0.384 (a)
TZDT-06		0.499	0.058	0.00580	8170	282.29	284.25	11139	21.96	0.373 (a)
AVERAGE:		0.499	0.058	0.00583	8122	279.06	282.58	11643	20.67	0.374
Minimum		0.498	0.058	0.00580	7250	250.00	251.74	10735	20.06	0.335
Maximum		0.500	0.060	0.00600	8980	310.28	312.43	12613	21.96	0.463
C.V., %:		0.13	1.40		6.92	7.07	6.99	5.61	3.83	12.86
TZDT-07		0.497	0.060	0.00600	8730	292.76	304.95	11886	22.80	23.75
TZDT-08	RTD	0.497	0.061	0.00610	8090	266.85	262.60	11906	20.22	21.41
TZDT-09		0.498	0.060	0.00600	8690	290.83	302.95	12178	21.49	22.39
TZDT-10		0.498	0.059	0.00590	8340	283.85	290.75	11682	22.29	22.83
TZDT-11		0.496	0.060	0.00600	8470	284.61	296.47	11959	21.78	22.69
TZDT-12		0.498	0.061	0.00610	7960	262.03	277.50	11316	21.22	22.47
AVERAGE:		0.497	0.060	0.00602	8380	280.15	292.54	11821	21.63	22.59
Minimum		0.496	0.059	0.00590	7960	262.03	277.50	11316	20.22	21.41
Maximum		0.498	0.061	0.00610	8730	292.76	304.95	12178	22.80	23.75
C.V., %:		0.16	1.25		3.73	4.55	3.76	2.49	4.14	14.06
TZDTSPA-02		0.500	0.058	0.00580	7990	275.52	277.43	14273	20.68	20.82
TZDTSPA-03	180°F/WET	0.499	0.059	0.00590	8110	274.92	281.60	13739	20.42	20.91
TZDTSPA-04		0.497	0.059	0.00580	8200	283.33	285.29	11420	22.27	22.43
TZDT-16		0.500	0.063	0.00630	7090	241.79	247.67	12962	21.27	21.79
TZDT-17		0.500	0.060	0.00600	8130	258.10	282.29	12118	18.71	20.46
TZDT-18		0.499	0.060	0.00600	8260	275.33	288.81	13244	20.79	21.86
AVERAGE:		0.499	0.060	0.00595	7963	268.16	276.85	12958	20.69	21.35
Minimum		0.497	0.058	0.00580	7090	241.79	247.67	11420	18.71	20.46
Maximum		0.500	0.063	0.00630	8260	283.33	286.81	14273	22.27	22.43
C.V., %:		0.24	3.14		5.49	5.72	5.30	8.08	5.66	3.44

NOTES: 1. Normalized stress and modulus are calculated using a nominal ply thickness of 0.00576 inch.
 2. Failure modes:
 (a) Tension failure at the grip tab.
 (b) Tension failure at the grip tab. Strain to failure was calculated from the actual stress divided by the actual modulus due to premature failure of the strain gage.

3. Specimens had a laminate orientation of [0₆] with a nominal laminate thickness of 0.0576 inch.
4. Wet specimens were moisture conditioned to an equilibrium moisture content of 0.79%.
5. Laminate 9914 had a delta dB loss of 5.0.
6. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDI-9914	29.50	61.41	1.77	0.055

Table 15. Transverse Tension Results for MR50/LTM25 Unidirectional Tape.

MPLR 35325

SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)	FAILURE STRENGTH (ksi)	STRAIN TO FAILURE (μ in/in)	TRANSVERSE MODULUS (Ms)	POISSONS RATIO	FAILURE MODE (2)
TNDT-01	-125°F/DRY	0.500	0.185	0.00617	406	4.39	3110	1.37	0.056	(a)
TNDT-02		0.501	0.183	0.00610	476	5.19	3828	1.35	0.052	(a)
TNDT-03		0.500	0.185	0.00617	390	4.22	3261	1.30	0.053	(a)
TNDT-04		0.501	0.183	0.00610	387	4.22	3078	1.35	0.050	(a)
TNDT-05		0.501	0.182	0.00607	323	3.54	2659	1.30	0.049	(a)
TNDT-06		0.501	0.182	0.00607	426	4.67	3562	1.28	0.051	(a)
		AVERAGE:	0.501	0.183	0.00611	401	4.37	3250	1.33	0.052
		Minimum	0.500	0.182	0.00607	323	3.54	2659	1.28	0.049
		Maximum	0.501	0.185	0.00617	476	5.19	3828	1.37	0.056
		C.V., %:	0.10	0.75	0.75	12.55	12.52	12.54	2.73	4.79
TNDT-07	RTD	0.500	0.188	0.00627	244	2.60	2661	1.04	0.040	(a)
TNDT-08		0.500	0.188	0.00627	319	3.39	3347	1.04	0.042	(a)
TNDT-09		0.500	0.189	0.00630	278	2.94	2893	1.03	0.022	(a)
TNDT-10		0.500	0.188	0.00627	244	2.60	2437	1.09	0.023	(a)
TNDT-11		0.500	0.189	0.00630	299	3.16	3022	1.08	0.020	(a)
TNDT-12		0.500	0.190	0.00633	298	3.14	3030	1.07	0.021	(a)
		AVERAGE:	0.500	0.189	0.00629	280	2.97	2898	1.06	0.028
		Minimum	0.500	0.188	0.00627	244	2.60	2437	1.03	0.020
		Maximum	0.500	0.190	0.00633	319	3.39	3347	1.09	0.042
		C.V., %:	0.00	0.43	0.43	11.05	10.91	10.94	2.44	36.63
TNDT-13	180°F/WET	0.501	0.184	0.00613	181	1.97	2374	0.83	0.075	(a)
TNDT-14		0.500	0.186	0.00620	177	1.90	2188	0.85	0.146	(a)
TNDT-15		0.500	0.185	0.00617	175	1.89	2312	0.83	0.263	(a)
TNDT-16		0.501	0.186	0.00620	175	1.87	2360	0.81	0.038	(a)
TNDT-17		0.500	0.186	0.00620	165	1.77	2003	1.00	0.046	(a)
TNDT-18		0.500	0.185	0.00617	186	2.01	2600	0.82	0.036	(b)
		AVERAGE:	0.500	0.185	0.00618	176	1.90	2306	0.86	0.101
		Minimum	0.500	0.184	0.00613	165	1.77	2003	0.81	0.036
		Maximum	0.501	0.186	0.00620	186	2.01	2600	1.00	0.263
		C.V., %:	0.10	0.44	0.44	4.10	4.36	8.67	8.24	89.03

NOTES: 1. Failure strength and transverse modulus were not normalized since they were deemed to be resin properties.

2. Failure modes:

- (a) Tension failure at the grip tab.
- (b) Tension failure in the gage area.

3. Specimens had a laminate orientation of [90₉₀] with a nominal laminate thickness of 0.1728 inch.

4. Wet specimens were moisture conditioned to an equilibrium moisture content of 0.80%.

5. Laminate 9917 had a delta dB loss of 16.5.

6. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9917	30.63	60.08	1.88	0.055

Table 16. Longitudinal Tension Results for CFS003/LTM25 Woven Cloth.

SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PERFILY THICKNESS (inch)	FAILURE LOAD (pounds)	FAILURE STRESS (ksi)		STRAIN TO FAILURE (in/in)	LONGITUDINAL MODULUS ACTUAL (Msi)	NORMALIZED (1) (Msi)	POISSON'S RATIO (3)	FAILURE MODE (2)
						ACTUAL	NORMALIZED (1)					
WZDT-01		0.500	0.075	0.00938	2540	67.73	70.26	84.97	7.73	8.02	0.074	(a)
WZDT-02	-125°F/DRY	0.501	0.077	0.00963	2890	74.92	79.79	972.9	7.70	8.20	0.017	(b)
WZDT-03		0.501	0.077	0.00963	2920	75.69	80.61	1083.9	6.99	7.44		(b)
WZDT-04		0.501	0.077	0.00963	3070	79.58	84.75	1074.0	7.41	7.89	0.116	(b)
WZDT-05		0.500	0.075	0.00938	2870	76.53	79.39	981.2	7.80	8.09	0.047	(b)
WZDT-06		0.500	0.074	0.00925	3040	82.16	84.09	1058.8	7.76	7.94	0.073	(b)
AVERAGE:		0.501	0.076	0.00948	2888.0	76.10	79.82	10032	7.57	7.93	0.065	
Minimum		0.500	0.074	0.00925	2540	67.73	70.26	84.97	6.99	7.44	0.017	
Maximum		0.501	0.077	0.00963	3070	82.16	84.75	1082.9	8.20	8.20	0.116	
C.V. %:		0.11	1.75	1.75	6.55	6.45	6.50	8.86	4.15	3.31	56.04	
WZDT-07		0.500	0.079	0.00988	3400	86.08	94.05	1148.9	7.09	7.75	0.035	(a)
WZDT-08		0.498	0.080	0.01000	3270	82.08	90.82	1123.5	6.94	7.68	0.029	(a)
WZDT-09	RTD	0.501	0.080	0.01000	3420	85.33	94.42	1184.9	6.76	7.48	0.044	(a)
WZDT-10		0.500	0.078	0.00975	3440	88.21	95.16	1173.3	7.19	7.76	0.054	(a)
WZDT-11		0.499	0.080	0.01000	3050	76.40	84.54	1060.6	7.05	7.80	0.051	(a)
WZDT-12		0.500	0.080	0.01000	2850	71.50	79.11	955.1	7.36	8.13	0.040	(a)
AVERAGE:		0.500	0.080	0.00994	3240	81.60	89.88	11077	7.06	7.77	0.042	
Minimum		0.498	0.078	0.00975	2860	71.50	79.11	955.1	6.76	7.48	0.029	
Maximum		0.501	0.080	0.01000	3440	88.21	95.16	1184.9	7.35	8.13	0.054	
C.V. %:		0.21	1.05	1.05	7.30	7.88	7.24	7.84	2.88	2.73	22.52	
WZDT-13		0.500	0.077	0.00963	3230	83.90	89.35	1195.9	6.86	7.30		(b)
WZDT-14		0.500	0.076	0.00950	3230	85.00	89.35	1191.1	6.67	7.01		(a)
WZDT-15	180°F/WET	0.500	0.075	0.00938	2940	78.40	81.33	1148.9	6.65	6.90		(a)
WZDT-16		0.501	0.074	0.00925	3130	84.43	86.41	1330.4	6.35	6.50	0.184	(b)
WZDT-17		0.500	0.074	0.00925	3070	82.97	84.92	1371.5	6.05	6.19	0.140	(b)
WZDT-18		0.501	0.075	0.00938	3210	85.43	88.62	1351.1	6.32	6.56	0.178	(b)
AVERAGE:		0.500	0.075	0.00940	3135	83.35	86.66	1264.8	6.48	6.74	0.167	
Minimum		0.500	0.074	0.00925	2940	78.40	81.33	1148.9	6.05	6.19	0.140	
Maximum		0.501	0.077	0.00963	3230	85.43	89.35	1371.5	6.86	7.30	0.184	
C.V. %:		0.10	1.56	1.56	3.66	3.09	3.64	7.64	4.54	5.95	14.26	

NOTES: 1. Normalized stress and modulus are calculated using a nominal ply thickness of 0.00904 inch.
 2. Failure modes:
 (a) Tension failure at the grip tab.
 (b) Tension failure at the grip tab. Strain to failure was calculated from the actual stress divided by the actual modulus due to premature failure of the strain gage.

3. Poisson's ratio was not reported for specimens WZDT-03, 13, 14, and 15 because of strain gage failures.

4. Specimens had a laminate orientation of [0] with a nominal laminate thickness of 0.0723 inch.

5. Wet specimens were moisture conditioned to an equilibrium moisture content of 1.02%.

6. Laminate 9918 had a delta dB loss of 5.9.

7. Laminate physical properties:

LAMINATE ID	FIBER CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in^3)
ASDL 9918	42.74	47.80	1.27	0.053

Table 17. Transverse Tension Results for CFS003/LTM25 Woven Cloth.

SPECIMEN D	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)		FAILURE STRESS ACTUAL (ksi)		STRAIN TO FAILURE (μin/in)		MODULUS ACTUAL (Msi)		POISSON'S RATIO (3)		FAILURE MODE (2)
WNDT-01		0.500	0.076	0.00950	32.10	84.47	88.80	10942	7.72	8.12					(b)
WNDT-02		0.499	0.076	0.00950	30.40	80.16	84.26	11026	7.27	7.64	0.093				(b)
WNDT-03	-125°F/DRY	0.500	0.076	0.00950	29.70	78.16	82.16	10325	7.57	7.96	0.106				(b)
WNDT-04		0.499	0.075	0.00938	26.70	71.34	74.01	9733	7.33	7.60	0.095				(b)
WNDT-05		0.500	0.075	0.00938	30.80	82.13	85.20	10241	8.02	8.32	0.106				(b)
WNDT-06		0.499	0.075	0.00938	32.70	87.37	90.64	11145	7.84	8.13	0.070				(b)
AVERAGE:		0.500	0.076	0.00944	30.40	80.61	84.18	10569	7.63	7.98	0.094				
Minimum		0.499	0.075	0.00938	26.70	71.34	74.01	9733	7.27	7.60	0.070				(b)
Maximum		0.500	0.076	0.00950	32.70	87.37	90.64	11145	8.02	8.32	0.106				(b)
C.V., %:		0.11	0.73	0.73	6.98	6.91	6.98	5.26	3.83	3.60	15.66				
WNDT-07		0.500	0.079	0.00988	35.90	89.87	98.20	12802	7.02	7.67	0.034				(b)
WNDT-08		0.498	0.078	0.00975	33.00	84.96	91.65	11692	7.04	7.60	0.009				(a)
WNDT-09	RTD	0.499	0.076	0.00950	33.20	87.54	92.02	10693	7.88	8.28	0.017				(a)
WNDT-10		0.500	0.076	0.00950	34.70	91.32	95.99	11352	7.64	8.03	0.016				(a)
WNDT-11		0.500	0.077	0.00963	34.30	89.09	94.88	10824	7.76	8.26	0.059				(a)
WNDT-12		0.500	0.076	0.00950	34.20	90.00	94.61	11046	7.77	8.17	0.033				(b)
AVERAGE:		0.500	0.077	0.00963	34.15	88.80	94.56	11402	7.52	8.00	0.028				
Minimum		0.498	0.076	0.00950	33.00	84.96	91.65	10693	7.02	7.60	0.009				(a)
Maximum		0.500	0.079	0.00988	35.50	91.32	98.20	12802	7.88	8.28	0.059				(a)
C.V., %:		0.17	1.64	1.64	2.74	2.54	2.60	6.81	5.13	3.76	64.84				
WNDT-13		0.500	0.073	0.00913	30.20	82.74	83.54	10336	7.85	7.93	0.079				(b)
WNDT-14		0.500	0.076	0.00950	32.40	85.26	89.63	12173	7.00	7.36	0.044				(b)
WNDT-15	180°F/WET	0.500	0.074	0.00925	31.70	85.68	87.69	14043	6.10	6.24	0.041				(b)
WNDT-16		0.500	0.074	0.00925	31.90	86.22	88.24	18432	5.25	5.37	0.009				(b)
WNDT-17		0.500	0.074	0.00925	31.00	83.78	85.75	18166	4.61	4.72	0.032				(b)
WNDT-18		0.500	0.074	0.00925	32.00	86.49	88.52	14858	5.82	5.96					
AVERAGE:		0.500	0.074	0.00927	31.53	85.03	87.23	14368	6.11	6.26	0.041				
Minimum		0.500	0.073	0.00913	30.20	82.74	83.54	10536	4.61	4.72	0.009				(b)
Maximum		0.500	0.076	0.00950	32.40	86.49	89.63	18166	7.85	7.93	0.079				(b)
C.V., %:		0.00	1.33	1.33	2.53	1.73	2.53	19.32	19.25	19.23	61.68				

NOTES: 1. Normalized stress is calculated using a nominal ply thickness of 0.00904 inch.

2. Failure modes:

- (a) Tension failure at the grip tab.
- (b) Tension failure at the grip tab. Strain to failure was calculated by dividing the stress by the modulus because of strain gage failures.

3. Poisson's ratio was not reported for specimens WNDT-01 and 18 because of strain gage failures.

4. Specimens had a laminate orientation of [0₆] with a nominal laminate thickness of 0.0723 inch.

5. Wet specimens were moisture conditioned to an equilibrium moisture content of 1.02%.

6. Laminate 9918 had a delta dB loss of 5.9.

7. Laminate physical properties:

LAMINATE ID	FIBER CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9918	42.74	47.80	1.27	0.053

Table 18. Open Hole Tension Results for MR50/LTM25 and CFS003/LTM25.

MPLR 28672								
SPECIMEN ID	MATERIAL	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)	FAILURE STRENGTH (ksi)	FAILURE MODE (1)
OHT-9-1			1.501	0.093	0.00581	7960	57.04	
OHT-9-2			1.500	0.092	0.00575	7700	55.81	(a)
OHT-9-3	MR50/LTM25 TAPE	Ambient	1.501	0.093	0.00581	8050	57.67	(a)
			AVERAGE:	1.501	0.093	0.00579	7903	56.84
			Minimum	1.500	0.092	0.00575	7700	55.81
			Maximum	1.501	0.093	0.00581	8050	57.67
			C.V., %:	0.04	0.63	0.63	2.30	1.67
OHT-12-1			1.500	0.150	0.00937	7300	32.47	
OHT-12-2			1.499	0.149	0.00933	7690	34.36	(a)
OHT-12-3	CFS003/LTM25 WOVEN	Ambient	1.501	0.151	0.00943	7760	34.28	(a)
			AVERAGE:	1.500	0.150	0.00938	7583	33.70
			Minimum	1.499	0.149	0.00933	7300	32.47
			Maximum	1.501	0.151	0.00943	7760	34.36
			C.V., %:	0.07	0.50	0.50	3.27	3.18

NOTES: 1. Failure mode:

- (a) Tension failure at the hole.
- 2. Tape specimens had a laminate orientation of [45/0/-45/90]2s with a nominal laminate thickness of 0.0922 inch.
- 3. Woven specimens had a laminate orientation of [45/0/-45/90]2s with a nominal laminate thickness of 0.1446 inch.
- 4. These specimens were fabricated, machined, and strain gaged by NASA and were not dried prior to test.

Table 19. In-Plane Shear Results for MR50/LTM25 Unidirectional Tape.

MPLR 35325									
SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)	SHEAR STRENGTH (ksi)	FAILURE SHEAR STRAIN (3) ($\mu\text{in/in}$)	SHEAR MODULUS (Msi)	FAILURE MODE (2)
TIPS-01	-125°F/DRY	1.001	0.180	0.00563	5849	16.23	22234	0.730	(a)
TIPS-02		1.001	0.181	0.00566	6011	16.59	22508	0.737	(a)
TIPS-03		1.001	0.183	0.00572	5630	15.37	21766	0.706	(a)
TIPS-04		1.001	0.181	0.00566	5894	16.27	22221	0.732	(a)
TIPS-05		1.001	0.183	0.00572	6006	16.39	21946	0.747	(a)
TIPS-06		1.001	0.182	0.00569	5747	15.77	21058	0.749	(a)
		AVERAGE:	1.001	0.182	0.00568	5856	16.10	21956	0.734
		Minimum	1.001	0.180	0.00563	5630	15.37	21058	0.706
		Maximum	1.001	0.183	0.00572	6011	16.59	22508	0.749
		C.V., %:	0.00	0.67	0.67	2.54	2.80	2.32	2.12
TIPS-07	RTD	1.001	0.181	0.00566	4576	12.63	21047	0.600	(a)
TIPS-08		1.001	0.182	0.00569	4703	12.91	22102	0.584	(a)
TIPS-09		1.001	0.181	0.00566	4771	13.17	20932	0.629	(a)
TIPS-10		1.001	0.183	0.00572	4747	12.96	21276	0.609	(a)
TIPS-11		1.000	0.181	0.00566	4742	13.10	21300	0.615	(a)
TIPS-12		0.998	0.182	0.00569	4639	12.77	20969	0.609	(a)
		AVERAGE:	1.000	0.182	0.00568	4696	12.92	21271	0.608
		Minimum	0.998	0.181	0.00566	4576	12.63	20932	0.584
		Maximum	1.001	0.183	0.00572	4771	13.17	22102	0.629
		C.V., %:	0.12	0.45	0.45	1.59	1.56	2.05	2.48
TIPS-13	180°F/WET	1.000	0.181	0.00566	2645	7.31	20240	0.361	(a)
TIPS-14		1.000	0.179	0.00559	2671	7.46	22405	0.333	(a)
TIPS-15		1.000	0.182	0.00569	2649	7.28	20852	0.349	(a)
TIPS-16		1.001	0.183	0.00572	2686	7.33	21251	0.345	(a)
TIPS-17		1.000	0.182	0.00569	2671	7.34	20846	0.352	(a)
TIPS-18		1.001	0.181	0.00566	2635	7.27	19868	0.366	(a)
		AVERAGE:	1.000	0.181	0.00567	2660	7.33	20910	0.351
		Minimum	1.000	0.179	0.00559	2635	7.27	19868	0.333
		Maximum	1.001	0.183	0.00572	2686	7.46	22405	0.366
		C.V., %:	0.05	0.75	0.75	0.73	0.94	4.22	3.35

- NOTES: 1. Shear strength and modulus were not normalized since they were deemed to be resin properties.
 2. Failure modes:
 (a) Tension failure in the gage area.
 3. Failure shear strain values were derived from the actual shear strength and modulus values.
 4. Specimens had a laminate orientation of [+45/-45]_{4S} with a nominal laminate thickness of 0.184 inch.
 5. Wet specimens were moisture conditioned to an equilibrium moisture content of 0.77%.
 6. Laminate 9916 had a delta dB loss of 14.8.
 7. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9916	29.38	60.23	3.85	0.054

Table 20. In-Plane Shear Results for CFS003/LTM25 Woven Cloth.

MPLR 35328									
SPECIMEN ID	TEST ENVIRONMENT	SPECIMEN WIDTH (inch)	SPECIMEN THICKNESS (inch)	PER-PLY THICKNESS (inch)	FAILURE LOAD (pounds)	SHEAR STRENGTH (ksi)	FAILURE SHEAR STRAIN (3) ($\mu\text{in/in}$)	SHEAR MODULUS (Ms)	FAILURE MODE (2)
WIPS-01	-125°F/DRY	1.001	0.218	0.00908	5889	13.49	22678	0.595	(a)
WIPS-02		1.001	0.220	0.00917	6367	14.46	24967	0.579	(a)
WIPS-03		1.001	0.221	0.00921	6255	14.14	23641	0.598	(a)
WIPS-04		1.001	0.221	0.00921	6240	14.10	24026	0.587	(a)
WIPS-05		1.001	0.221	0.00921	6391	14.44	25078	0.576	(a)
WIPS-06		1.001	0.222	0.00925	6406	14.41	24471	0.589	(a)
		AVERAGE:	1.001	0.221	0.00919	6258	14.17	24144	0.587
		Minimum	1.001	0.218	0.00908	5889	13.49	22678	0.576
		Maximum	1.001	0.222	0.00925	6406	14.46	25078	0.598
		C.V., %:	0.00	0.63	0.63	3.10	2.60	3.74	1.47
WIPS-07	RTD	1.001	0.221	0.00921	5474	12.37	29180	0.424	(a)
WIPS-08		1.001	0.222	0.00925	5518	12.42	29989	0.414	(a)
WIPS-09		1.001	0.222	0.00925	5401	12.15	30230	0.402	(a)
WIPS-10		1.001	0.223	0.00929	5528	12.38	28796	0.430	(a)
WIPS-11		1.001	0.222	0.00925	5386	12.12	29630	0.409	(a)
WIPS-12		1.000	0.223	0.00929	5337	11.97	29547	0.405	(a)
		AVERAGE:	1.001	0.222	0.00926	5441	12.23	29562	0.414
		Minimum	1.000	0.221	0.00921	5337	11.97	28796	0.402
		Maximum	1.001	0.223	0.00929	5528	12.42	30230	0.430
		C.V., %:	0.04	0.34	0.34	1.42	1.49	1.77	2.66
WIPS-13		1.000	0.224	0.00933	3521	7.86	21127	0.372	(a)
WIPS-14	180°F/WET	1.000	0.224	0.00933	3474	7.75	21015	0.369	(a)
WIPS-15		1.000	0.221	0.00921	3385	7.66	20698	0.370	(a)
WIPS-16		1.000	0.223	0.00929	3427	7.68	20656	0.372	(a)
WIPS-17		1.000	0.224	0.00933	3410	7.61	20352	0.374	(a)
WIPS-18		1.000	0.224	0.00933	3459	7.72	21749	0.355	(a)
		AVERAGE:	1.000	0.223	0.00931	3446	7.71	20933	0.369
		Minimum	1.000	0.221	0.00921	3385	7.61	20352	0.355
		Maximum	1.000	0.224	0.00933	3521	7.86	21749	0.374
		C.V., %:	0.00	0.54	0.54	1.42	1.12	2.32	1.88

- NOTES: 1. Shear strength and modulus were not normalized since they were deemed to be resin properties.
 2. Failure modes:
 (a) Tension failure in the gage area.
 3. Failure shear strain values were derived from the actual shear strength and modulus values.
 4. Specimens had a laminate orientation of [+45/-45]3S with a nominal laminate thickness of 0.217 inch.
 5. Wet specimens were moisture conditioned to an equilibrium moisture content of 1.00%.
 6. Laminate 9919 had a delta dB loss of 13.9.
 7. Laminate physical properties:

LAMINATE ID	RESIN CONTENT (Wt. %)	FIBER VOLUME (Vol. %)	VOID VOLUME (Vol. %)	DENSITY ρ (lb/in ³)
ASDL 9919	43.93	46.63	1.21	0.053

Table 21. Summary of -125°F Mechanical Properties for MR50/LTM25.

Properties		Measured	Normalized
E_1^t (Msi)	Mean	20.67	20.93
	Minimum	20.06	20.20
	Maximum	21.96	22.11
	C.V. (%)	3.83	3.53
v_{12}^t	Mean	0.374	
	Minimum	0.335	
	Maximum	0.463	
	C.V. (%)	12.86	
E_1^c (Msi)	Mean	22.19	20.99
	Minimum	20.97	20.01
	Maximum	23.40	22.34
	C.V. (%)	4.07	4.38
v_{12}^c	Mean	0.364	
	Minimum	0.344	
	Maximum	0.422	
	C.V. (%)	8.07	
E_2^t (Msi)	Mean	1.33	
	Minimum	1.28	
	Maximum	1.37	
	C.V. (%)	2.73	
v_{21}^t	Mean	0.052	
	Minimum	0.049	
	Maximum	0.056	
	C.V. (%)	4.79	
E_2^c (Msi)	Mean	1.55	
	Minimum	1.35	
	Maximum	1.92	
	C.V. (%)	13.10	
v_{21}^c	Mean	0.029	
	Minimum	0.024	
	Maximum	0.035	
	C.V. (%)	18.15	
G_{12}^s (Msi)	Mean	0.734	
	Minimum	0.706	
	Maximum	0.749	
	C.V. (%)	2.12	

Table 22. Summary of -125°F Mechanical Properties for MR50/LTM25, Continued.

Properties		Measured	Normalized
F_1^{tu} (ksi)	Mean	279.06	282.58
	Minimum	250.00	251.74
	Maximum	310.28	312.43
	C.V. (%)	7.07	6.99
F_1^{cu} (ksi)	Mean	216.13	205.68
	Minimum	195.03	189.62
	Maximum	236.11	225.45
	C.V. (%)	6.14	5.62
F_2^{tu} (ksi)	Mean	4.37	
	Minimum	3.54	
	Maximum	5.19	
	C.V. (%)	12.52	
F_2^{cu} (ksi)	Mean	34.66	
	Minimum	31.99	
	Maximum	36.76	
	C.V. (%)	6.09	
F_{12}^{su} (ksi)	Mean	16.10	
	Minimum	15.37	
	Maximum	16.59	
	C.V. (%)	2.80	
ϵ_1^{tu} ($\mu\text{in/in}$)	Mean	11643	
	Minimum	10735	
	Maximum	12613	
	C.V. (%)	5.61	
ϵ_1^{cu} ($\mu\text{in/in}$)	Mean	9741	
	Minimum	8790	
	Maximum	10641	
	C.V. (%)	6.14	
ϵ_2^{tu} ($\mu\text{in/in}$)	Mean	3250	
	Minimum	2659	
	Maximum	3828	
	C.V. (%)	12.54	
ϵ_2^{cu} ($\mu\text{in/in}$)	Mean	22631	
	Minimum	18478	
	Maximum	27203	
	C.V. (%)	14.86	
γ_{12}^{su} ($\mu\text{in/in}$)	Mean	21956	
	Minimum	21058	
	Maximum	22508	
	C.V. (%)	2.32	

Table 23. Summary of RTD Mechanical Properties for MR50/LTM25.

Properties		Measured	Normalized
E_1^t (Msi)	Mean	21.63	22.59
	Minimum	20.22	21.41
	Maximum	22.80	23.75
	C.V. (%)	4.14	3.34
v_{12}^t	Mean	0.345	
	Minimum	0.264	
	Maximum	0.387	
	C.V. (%)	14.06	
E_1^c (Msi)	Mean	22.28	21.70
	Minimum	21.32	21.09
	Maximum	23.57	22.49
	C.V. (%)	4.58	2.40
v_{12}^c	Mean	0.366	
	Minimum	0.330	
	Maximum	0.395	
	C.V. (%)	7.13	
E_2^t (Msi)	Mean	1.06	
	Minimum	1.03	
	Maximum	1.09	
	C.V. (%)	2.44	
v_{21}^t	Mean	0.028	
	Minimum	0.020	
	Maximum	0.042	
	C.V. (%)	36.63	
E_2^c (Msi)	Mean	1.21	
	Minimum	1.10	
	Maximum	1.35	
	C.V. (%)	7.90	
v_{21}^c	Mean	0.011	
	Minimum	0.010	
	Maximum	0.013	
	C.V. (%)	11.18	
G_{12}^s (Msi)	Mean	0.608	
	Minimum	0.584	
	Maximum	0.629	
	C.V. (%)	2.48	

Table 24. Summary of RTD Mechanical Properties for MR50/LTM25, Continued.

Properties		Measured	Normalized
F_1^{tu} (ksi)	Mean	280.15	292.54
	Minimum	262.03	277.50
	Maximum	292.76	304.95
	C.V. (%)	4.55	3.76
F_1^{cu} (ksi)	Mean	170.52	164.63
	Minimum	148.51	144.39
	Maximum	195.60	183.37
	C.V. (%)	8.90	7.53
F_2^{tu} (ksi)	Mean	2.97	
	Minimum	2.60	
	Maximum	3.39	
	C.V. (%)	10.91	
F_2^{cu} (ksi)	Mean	21.08	
	Minimum	20.00	
	Maximum	22.06	
	C.V. (%)	3.74	
F_{12}^{su} (ksi)	Mean	12.92	
	Minimum	12.63	
	Maximum	13.17	
	C.V. (%)	1.56	
ϵ_1^{tu} ($\mu\text{in/in}$)	Mean	11821	
	Minimum	11316	
	Maximum	12178	
	C.V. (%)	2.49	
ϵ_1^{cu} ($\mu\text{in/in}$)	Mean	7655	
	Minimum	6667	
	Maximum	8780	
	C.V. (%)	8.90	
ϵ_2^{tu} ($\mu\text{in/in}$)	Mean	2898	
	Minimum	2437	
	Maximum	3347	
	C.V. (%)	10.94	
ϵ_2^{cu} ($\mu\text{in/in}$)	Mean	25183	
	Minimum	22739	
	Maximum	28337	
	C.V. (%)	7.97	
γ_{12}^{su} ($\mu\text{in/in}$)	Mean	21271	
	Minimum	20932	
	Maximum	22102	
	C.V. (%)	2.05	

Table 25. Summary of 180°F/Wet Mechanical Properties for MR50/LTM25.

Properties		Measured	Normalized
E_1^t (Msi)	Mean	20.69	21.35
	Minimum	18.71	20.46
	Maximum	22.27	22.43
	C.V. (%)	5.66	3.44
v_{12}^t	Mean	0.359	
	Minimum	0.321	
	Maximum	0.427	
	C.V. (%)	11.20	
E_1^c (Msi)	Mean	22.30	21.74
	Minimum	21.41	21.05
	Maximum	23.77	22.29
	C.V. (%)	3.52	1.94
v_{12}^c	Mean	0.431	
	Minimum	0.361	
	Maximum	0.520	
	C.V. (%)	12.39	
E_2^t (Msi)	Mean	0.86	
	Minimum	0.81	
	Maximum	1.00	
	C.V. (%)	8.24	
v_{21}^t	Mean	0.101	
	Minimum	0.036	
	Maximum	0.263	
	C.V. (%)	89.03	
E_2^c (Msi)	Mean	0.96	
	Minimum	0.85	
	Maximum	1.09	
	C.V. (%)	10.55	
v_{21}^c	Mean	0.012	
	Minimum	0.007	
	Maximum	0.023	
	C.V. (%)	56.07	
G_{12}^s (Msi)	Mean	0.351	
	Minimum	0.333	
	Maximum	0.366	
	C.V. (%)	3.35	

Table 26. Summary of 180°F/Wet Mechanical Properties for MR50/LTM25, Continued.

Properties		Measured	Normalized
F_1^{tu} (ksi)	Mean	268.16	276.85
	Minimum	241.79	247.67
	Maximum	283.33	286.81
	C.V. (%)	5.72	5.30
F_1^{cu} (ksi)	Mean	113.33	106.85
	Minimum	93.99	89.75
	Maximum	125.79	117.82
	C.V. (%)	10.24	9.82
F_2^{tu} (ksi)	Mean	1.90	
	Minimum	1.77	
	Maximum	2.01	
	C.V. (%)	4.36	
F_2^{cu} (ksi)	Mean	10.76	
	Minimum	9.85	
	Maximum	11.93	
	C.V. (%)	7.51	
F_{12}^{su} (ksi)	Mean	7.33	
	Minimum	7.27	
	Maximum	7.46	
	C.V. (%)	0.94	
ϵ_1^{tu} (μin/in)	Mean	12958	
	Minimum	11420	
	Maximum	14273	
	C.V. (%)	8.08	
ϵ_1^{cu} (μin/in)	Mean	5081	
	Minimum	4241	
	Maximum	5640	
	C.V. (%)	10.24	
ϵ_2^{tu} (μin/in)	Mean	2306	
	Minimum	2003	
	Maximum	2600	
	C.V. (%)	8.67	
ϵ_2^{cu} (μin/in)	Mean	25264	
	Minimum	21519	
	Maximum	28343	
	C.V. (%)	11.61	
γ_{12}^{su} (μin/in)	Mean	20910	
	Minimum	19868	
	Maximum	22405	
	C.V. (%)	4.22	

Table 27. Summary of -125°F Mechanical Properties for CFS003/LTM25.

Properties		Measured	Normalized
E_1^t (Msi)	Mean	7.57	7.93
	Minimum	6.99	7.44
	Maximum	7.80	8.20
	C.V. (%)	4.15	3.31
v_{12}^t	Mean	0.065	
	Minimum	0.017	
	Maximum	0.116	
	C.V. (%)	56.04	
E_1^c (Msi)	Mean	7.46	7.08
	Minimum	6.66	6.45
	Maximum	8.74	8.22
	C.V. (%)	10.45	9.58
v_{12}^c	Mean	0.076	
	Minimum	0.050	
	Maximum	0.100	
	C.V. (%)	22.68	
E_2^t (Msi)	Mean	7.58	7.83
	Minimum	7.27	7.31
	Maximum	8.02	8.32
	C.V. (%)	3.90	4.78
v_{21}^t	Mean	0.094	
	Minimum	0.070	
	Maximum	0.106	
	C.V. (%)	13.98	
E_2^c (Msi)	Mean	7.84	7.34
	Minimum	7.43	6.99
	Maximum	8.10	7.62
	C.V. (%)	3.63	3.36
v_{21}^c	Mean	0.068	
	Minimum	0.060	
	Maximum	0.078	
	C.V. (%)	10.48	
G_{12}^s (Msi)	Mean	0.587	
	Minimum	0.576	
	Maximum	0.598	
	C.V. (%)	1.47	

Table 28. Summary of -125°F Mechanical Properties for CFS003/LTM25, Continued.

Properties	Measured	Normalized
F_1^{tu} (ksi)	Mean	76.10
	Minimum	67.73
	Maximum	82.16
	C.V. (%)	6.45
F_1^{cu} (ksi)	Mean	112.95
	Minimum	108.27
	Maximum	115.79
	C.V. (%)	3.01
F_2^{tu} (ksi)	Mean	79.93
	Minimum	71.34
	Maximum	87.37
	C.V. (%)	6.56
F_2^{cu} (ksi)	Mean	100.45
	Minimum	93.29
	Maximum	105.28
	C.V. (%)	4.39
F_{12}^{su} (ksi)	Mean	14.17
	Minimum	13.49
	Maximum	14.46
	C.V. (%)	2.60
ϵ_1^{tu} ($\mu\text{in/in}$)	Mean	10032
	Minimum	8497
	Maximum	10829
	C.V. (%)	8.85
ϵ_1^{cu} ($\mu\text{in/in}$)	Mean	15135
	Minimum	14508
	Maximum	15515
	C.V. (%)	3.01
ϵ_2^{tu} ($\mu\text{in/in}$)	Mean	10544
	Minimum	9733
	Maximum	11145
	C.V. (%)	5.12
ϵ_2^{cu} ($\mu\text{in/in}$)	Mean	12815
	Minimum	11901
	Maximum	13430
	C.V. (%)	4.39
γ_{12}^{su} ($\mu\text{in/in}$)	Mean	24144
	Minimum	22678
	Maximum	25078
	C.V. (%)	3.74

Table 29. Summary of RTD Mechanical Properties for CFS003/LTM25.

Properties		Measured	Normalized
E_1^t (Msi)	Mean	7.06	7.77
	Minimum	6.76	7.48
	Maximum	7.35	8.13
	C.V. (%)	2.88	2.73
v_{12}^t	Mean	0.042	
	Minimum	0.029	
	Maximum	0.054	
	C.V. (%)	22.52	
E_1^c (Msi)	Mean	7.20	6.84
	Minimum	6.69	6.29
	Maximum	7.81	7.45
	C.V. (%)	5.74	6.04
v_{12}^c	Mean	0.033	
	Minimum	0.011	
	Maximum	0.079	
	C.V. (%)	84.49	
E_2^t (Msi)	Mean	7.52	8.00
	Minimum	7.02	7.60
	Maximum	7.88	8.28
	C.V. (%)	5.13	3.76
v_{21}^t	Mean	0.028	
	Minimum	0.009	
	Maximum	0.059	
	C.V. (%)	64.84	
E_2^c (Msi)	Mean	7.54	7.05
	Minimum	7.39	6.95
	Maximum	7.67	7.20
	C.V. (%)	1.44	1.26
v_{21}^c	Mean	0.035	
	Minimum	0.011	
	Maximum	0.063	
	C.V. (%)	74.94	
G_{12}^s (Msi)	Mean	0.414	
	Minimum	0.402	
	Maximum	0.430	
	C.V. (%)	2.66	

Table 30. Summary of RTD Mechanical Properties for CFS003/LTM25, Continued.

Properties		Measured	Normalized
F_1^{tu} (ksi)	Mean	81.60	89.68
	Minimum	71.50	79.11
	Maximum	88.21	95.16
	C.V. (%)	7.88	7.24
F_1^{cu} (ksi)	Mean	93.12	93.16
	Minimum	89.49	89.81
	Maximum	98.11	97.71
	C.V. (%)	3.50	3.17
F_2^{tu} (ksi)	Mean	88.80	94.56
	Minimum	84.96	91.65
	Maximum	91.32	98.20
	C.V. (%)	2.54	2.60
F_2^{cu} (ksi)	Mean	81.69	80.64
	Minimum	74.08	72.75
	Maximum	90.28	89.90
	C.V. (%)	7.69	8.39
F_{12}^{su} (ksi)	Mean	12.23	
	Minimum	11.97	
	Maximum	12.42	
	C.V. (%)	1.49	
$\varepsilon_1^{\text{tu}}$ ($\mu\text{in/in}$)	Mean	11077	
	Minimum	9551	
	Maximum	11849	
	C.V. (%)	7.84	
$\varepsilon_1^{\text{cu}}$ ($\mu\text{in/in}$)	Mean	12929	
	Minimum	12425	
	Maximum	13622	
	C.V. (%)	3.50	
$\varepsilon_2^{\text{tu}}$ ($\mu\text{in/in}$)	Mean	11402	
	Minimum	10693	
	Maximum	12802	
	C.V. (%)	6.81	
$\varepsilon_2^{\text{cu}}$ ($\mu\text{in/in}$)	Mean	10839	
	Minimum	9830	
	Maximum	11978	
	C.V. (%)	7.69	
γ_{12}^{su} ($\mu\text{in/in}$)	Mean	29562	
	Minimum	28796	
	Maximum	30230	
	C.V. (%)	1.77	

Table 31. Summary of 180°F/Wet Mechanical Properties for CFS003/LTM25.

Properties		Measured	Normalized
E_1^t (Msi)	Mean	6.48	6.74
	Minimum	6.05	6.19
	Maximum	6.86	7.30
	C.V. (%)	4.54	5.95
v_{12}^t	Mean	0.167	
	Minimum	0.140	
	Maximum	0.184	
	C.V. (%)	14.26	
E_1^c (Msi)	Mean	8.37	7.97
	Minimum	7.85	7.49
	Maximum	9.28	8.85
	C.V. (%)	5.94	5.84
v_{12}^c	Mean	0.051	
	Minimum	0.014	
	Maximum	0.076	
	C.V. (%)	51.52	
E_2^t (Msi)	Mean	6.11	6.26
	Minimum	4.61	4.72
	Maximum	7.85	7.93
	C.V. (%)	19.25	19.23
v_{21}^t	Mean	0.041	
	Minimum	0.009	
	Maximum	0.079	
	C.V. (%)	61.68	
E_2^c (Msi)	Mean	7.22	6.77
	Minimum	6.96	6.53
	Maximum	7.63	7.18
	C.V. (%)	3.39	3.64
v_{21}^c	Mean	0.023	
	Minimum	0.017	
	Maximum	0.029	
	C.V. (%)	36.89	
G_{12}^s (Msi)	Mean	0.369	
	Minimum	0.355	
	Maximum	0.374	
	C.V. (%)	1.88	

Table 32. Summary of 180°F/Wet Mechanical Properties for CFS003/LTM25, Continued.

Properties		Measured	Normalized
F_1^{tu} (ksi)	Mean	83.35	86.66
	Minimum	78.40	81.33
	Maximum	85.43	89.35
	C.V. (%)	3.09	3.64
F_1^{cu} (ksi)	Mean	55.07	54.33
	Minimum	49.01	48.13
	Maximum	60.00	58.92
	C.V. (%)	7.65	7.55
F_2^{tu} (ksi)	Mean	85.03	87.23
	Minimum	82.74	83.54
	Maximum	86.49	89.63
	C.V. (%)	1.73	2.53
F_2^{cu} (ksi)	Mean	54.04	52.06
	Minimum	50.76	49.14
	Maximum	60.02	57.29
	C.V. (%)	6.32	5.97
F_{12}^{su} (ksi)	Mean	7.71	
	Minimum	7.61	
	Maximum	7.86	
	C.V. (%)	1.12	
ϵ_1^{tu} ($\mu\text{in/in}$)	Mean	12648	
	Minimum	11489	
	Maximum	13715	
	C.V. (%)	7.64	
ϵ_1^{cu} ($\mu\text{in/in}$)	Mean	6581	
	Minimum	5857	
	Maximum	7170	
	C.V. (%)	7.65	
ϵ_2^{tu} ($\mu\text{in/in}$)	Mean	14368	
	Minimum	10536	
	Maximum	18166	
	C.V. (%)	19.32	
ϵ_2^{cu} ($\mu\text{in/in}$)	Mean	7486	
	Minimum	7031	
	Maximum	8315	
	C.V. (%)	6.32	
γ_{12}^{su} ($\mu\text{in/in}$)	Mean	20933	
	Minimum	20352	
	Maximum	21749	
	C.V. (%)	2.32	

Table 33. Summary of RDS Tg Data.

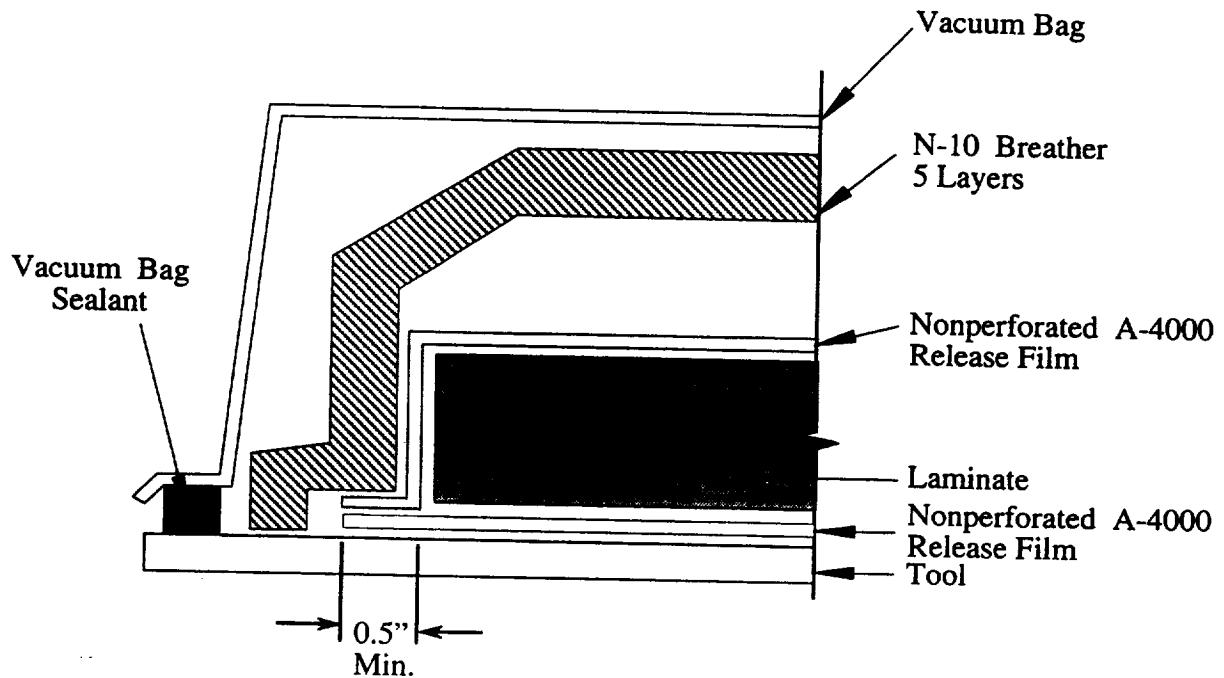
Environmental Condition	Tg (°F)	
	Tape	Woven
Dry	265	268
Moisture Conditioned	218	225

Table 34. Summary of Coefficient of Thermal Expansion Data.

Orientation	CTE ($\mu\text{in/in/}^{\circ}\text{F}$)	
	Measured at Room Temperature	
	Tape	Woven
Longitudinal	-0.24	2.13
Transverse	20.8	2.11

Table 35. Summary of Laminate Physical Analysis.

Panel Number	ASDL Number	Material	Resin Content (Wt. %)	Fiber Volume (Vol. %)	Void Volume (Vol. %)	Density ρ (lb/in ³)	End User
1	9914	Tape	29.50	61.41	1.77	0.0554	Northrop
2	9915	Tape	27.97	62.85	2.19	0.0555	Northrop
3	9916	Tape	29.38	60.23	3.85	0.0542	Northrop
4	9917	Tape	30.63	60.08	1.88	0.0551	Northrop
5	9918	Woven	42.74	47.80	1.27	0.0528	Northrop
6	9919	Woven	43.93	46.63	1.21	0.0526	Northrop
13	9926	Tape	30.54	60.47	1.42	0.0553	NASA
14	9927	Tape	30.55	60.35	1.59	0.0552	NASA
15	9928	Tape	30.40	60.37	1.81	0.0552	NASA
16	9929	Tape	30.07	60.64	1.99	0.0551	NASA
17	9930	Woven	44.15	46.12	1.82	0.0522	NASA
18	9931	Woven	43.66	46.67	1.68	0.0524	NASA



Cure Cycle

1. Apply vacuum (no less than 25 inches of Hg).
2. Ramp temperature at a rate of 1°F/minute.
3. Hold at 150°F for 9.5 hours.
4. Cool down under vacuum, at a rate of 2°F/minute.

Postcure

1. Heat laminate freestanding at a rate of 2°F/minute.
2. Hold at 250°F for 120 minutes.
3. Cool down to 140°F at a rate of 6°F/minute.

Figure 1. Laminate Bagging Profile and Cure Cycle.

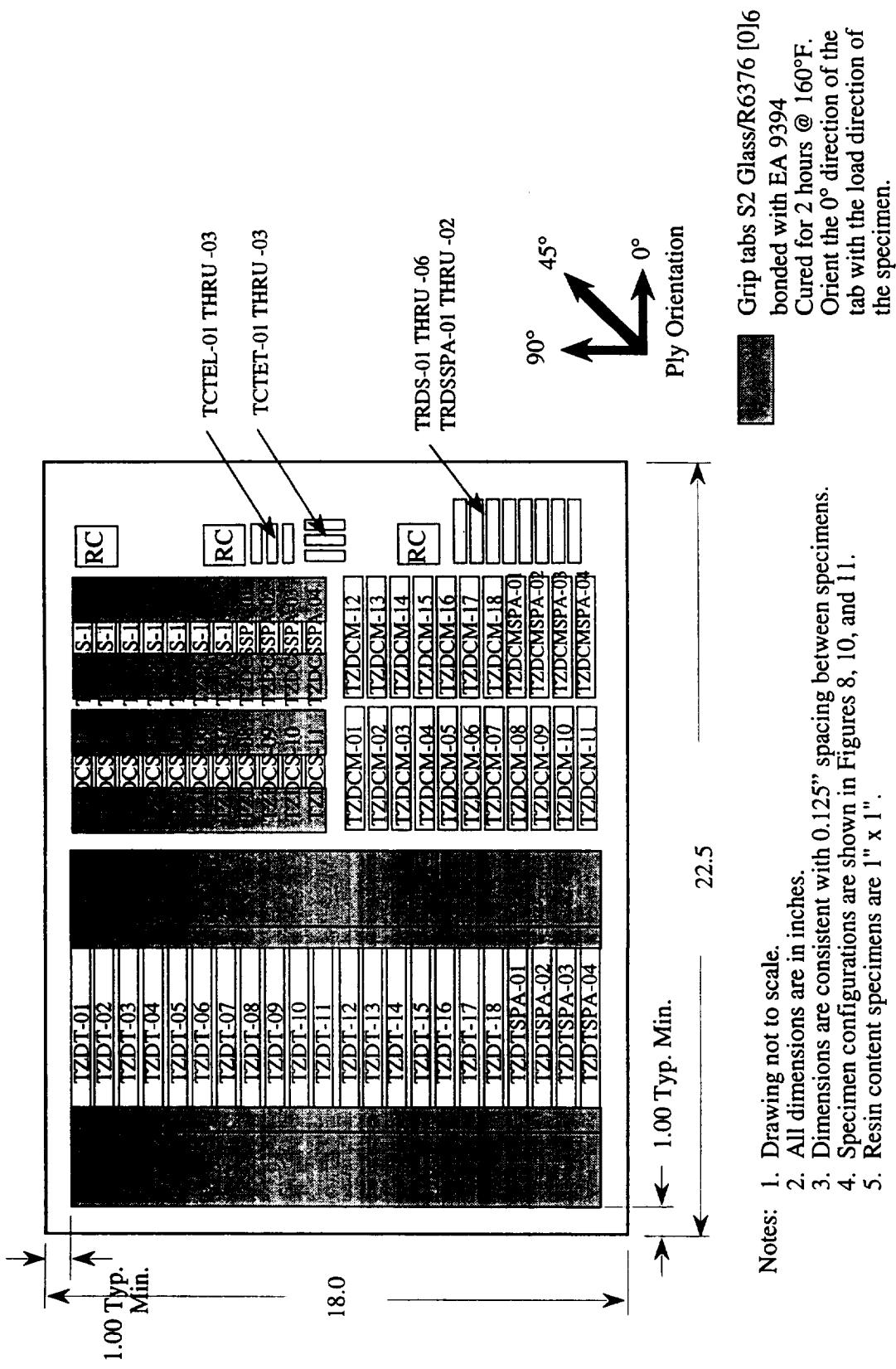
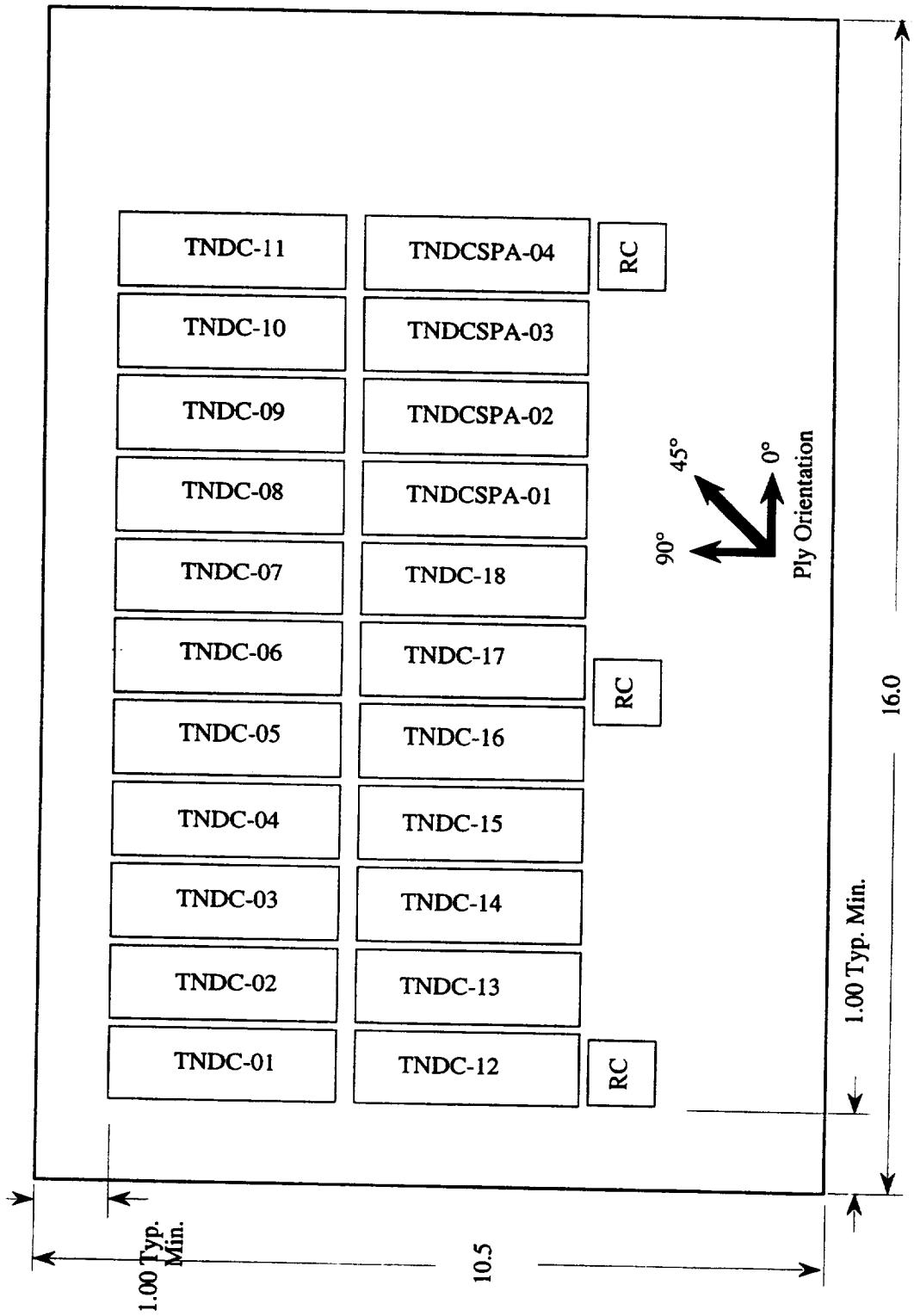
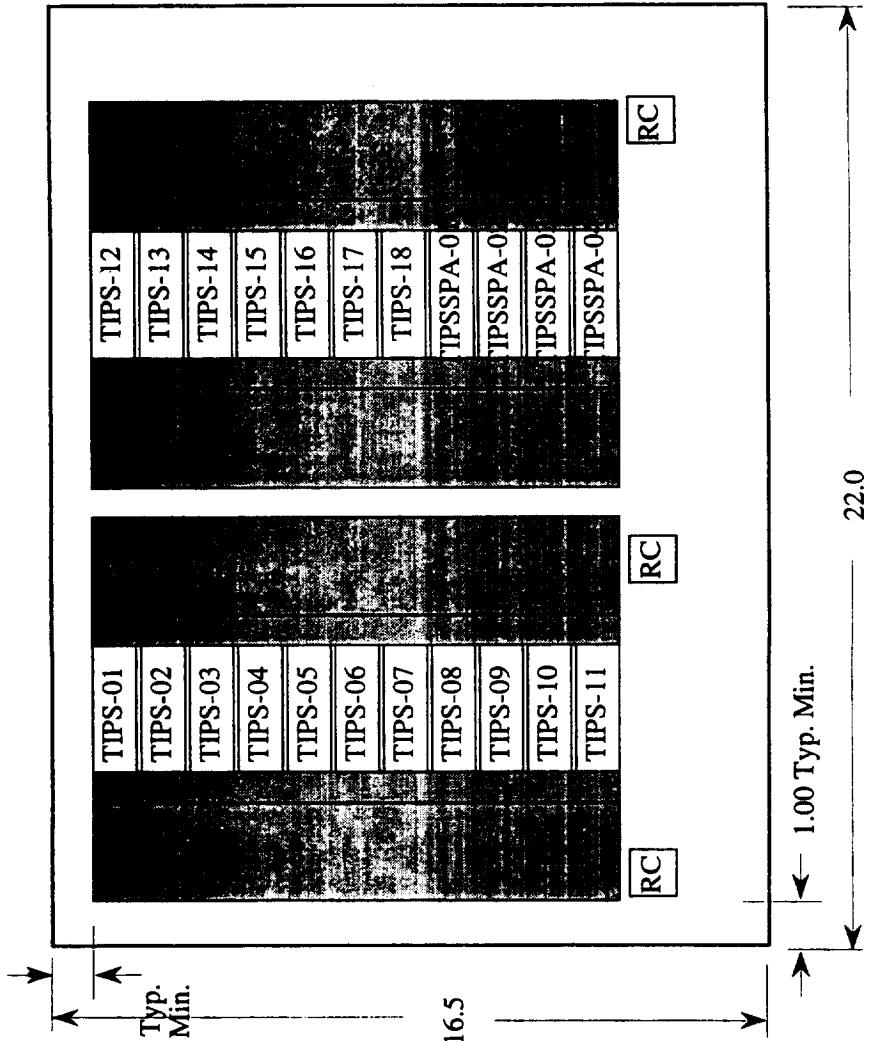


Figure 2. Panel 1, Layout for 0° Compression and Tension [O]10, Tnom = 0.0576", Tape Material.



- Notes:
1. Drawing not to scale.
 2. All dimensions are in inches.
 3. Dimensions are consistent with 0.125" spacing between specimens.
 4. Specimen configuration is shown in Figure 12.
 5. Resin content specimens are 1" x 1".

Figure 3. Panel 2, Layout for 90° Compression [0]24, Thom = 0.138" Tape Material.

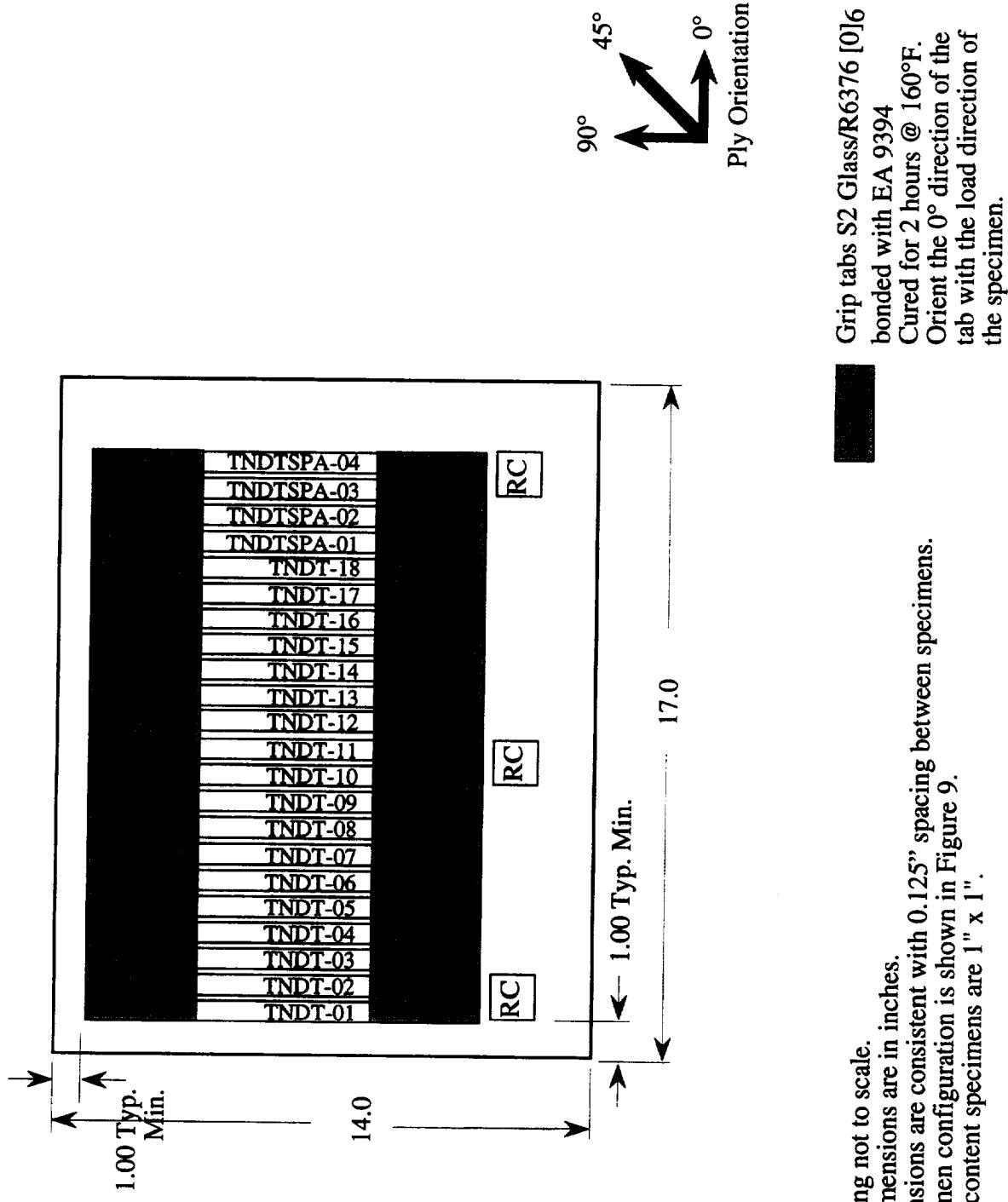


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Grip tabs S2 Glass/R6376 [0]6
bonded with EA 9394
Cured for 2 hours @ 160°F.
Orient the 0° direction of the
tab with the load direction of
the specimen.

- Notes:
1. Drawing not to scale.
 2. All dimensions are in inches.
 3. Dimensions are consistent with 0.125" spacing between specimens.
 4. Specimen configuration is shown in Figure 13.
 5. Resin content specimens are 1" x 1".

Figure 4. Panel 3, Layout for ± 45 In-Plane Shear [+45/-45]8S, Thom = 0.184" Tape Material.



Grip tabs S2 Glass/R6376 [0]6
bonded with EA 9394
Cured for 2 hours @ 160°F.
Orient the 0° direction of the
tab with the load direction of
the specimen.

- Notes:
1. Drawing not to scale.
 2. All dimensions are in inches.
 3. Dimensions are consistent with 0.125" spacing between specimens.
 4. Specimen configuration is shown in Figure 9.
 5. Resin content specimens are 1" x 1".

Figure 5. Panel 4, Layout for 90° Tension [0]30, $T_{nom} = 0.173"$, Tape Material.

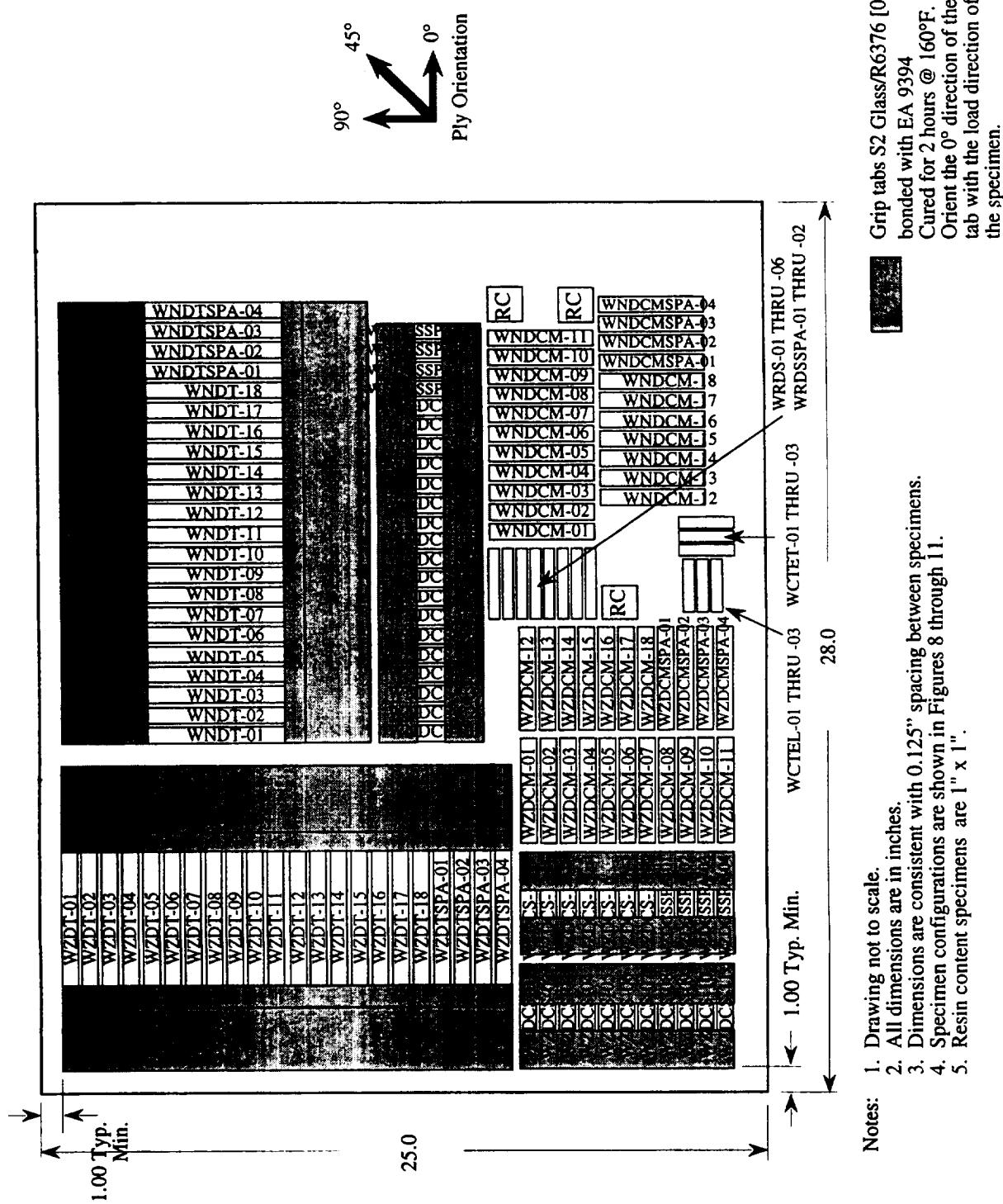


Figure 6. Panel 5, Layout for 0° and 90° Compression and Tension [0]8. Trnom = 0.0723", Woven Material.

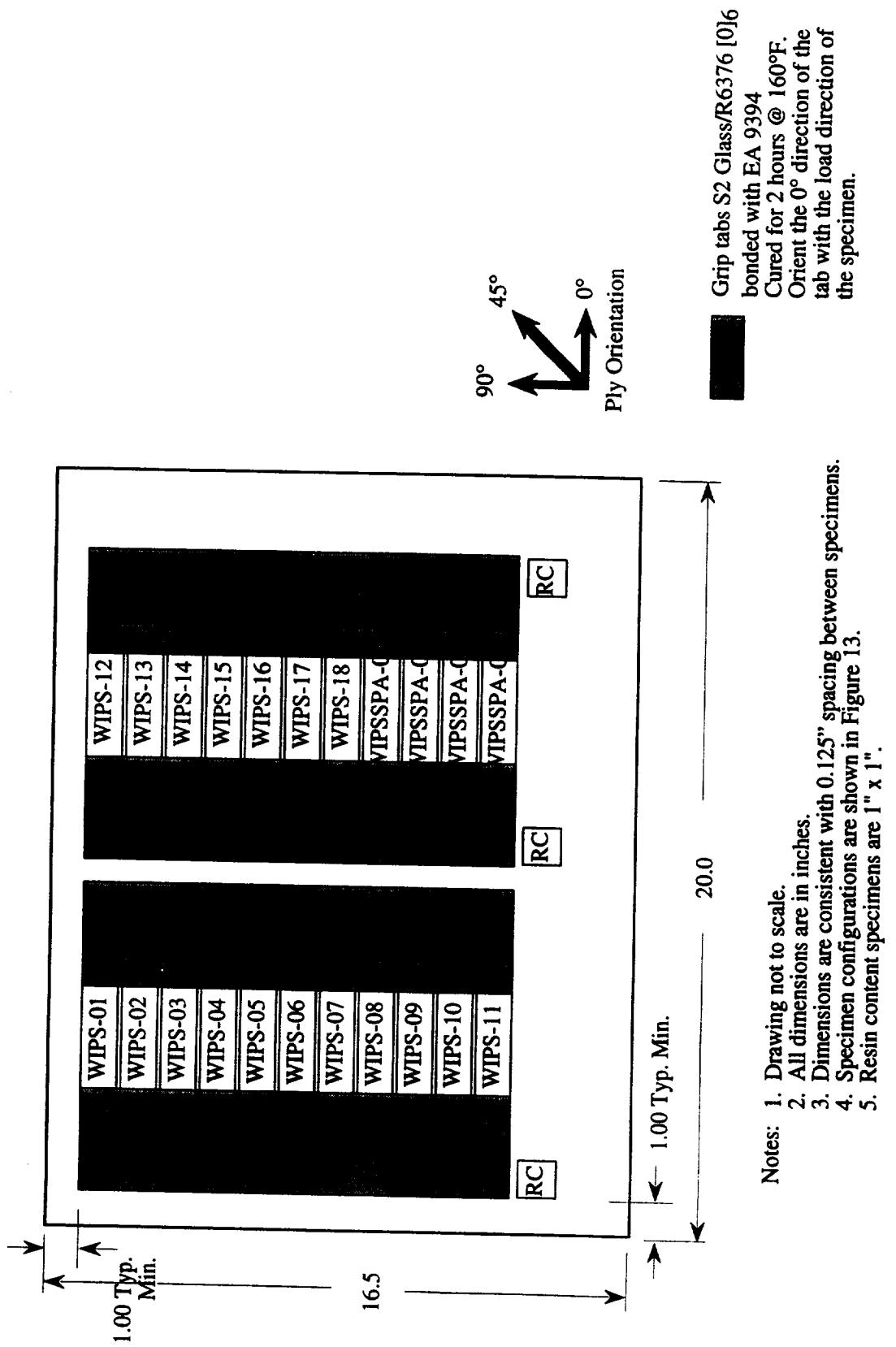
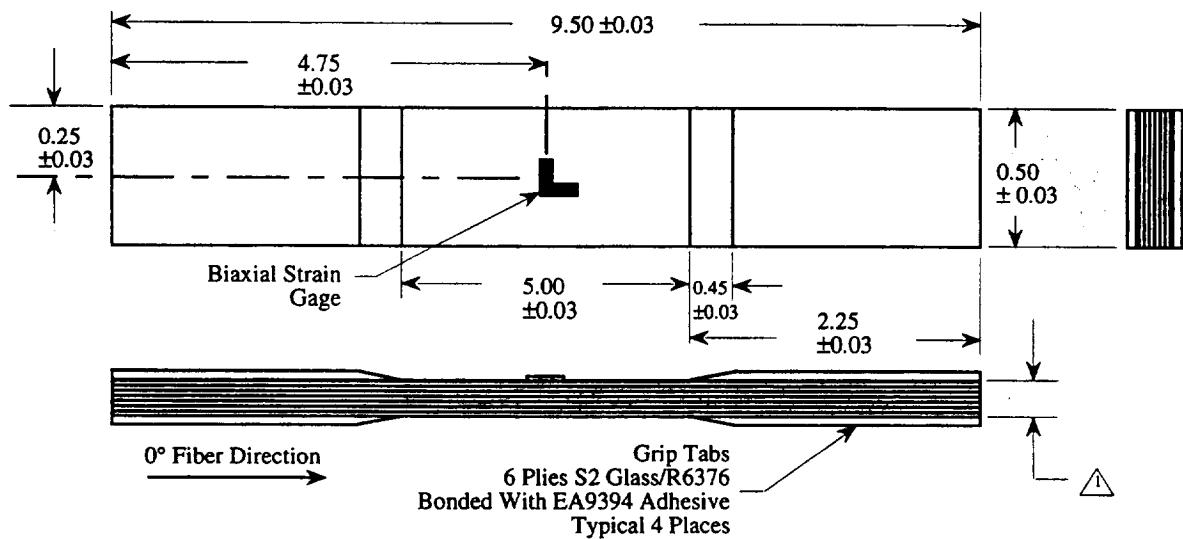
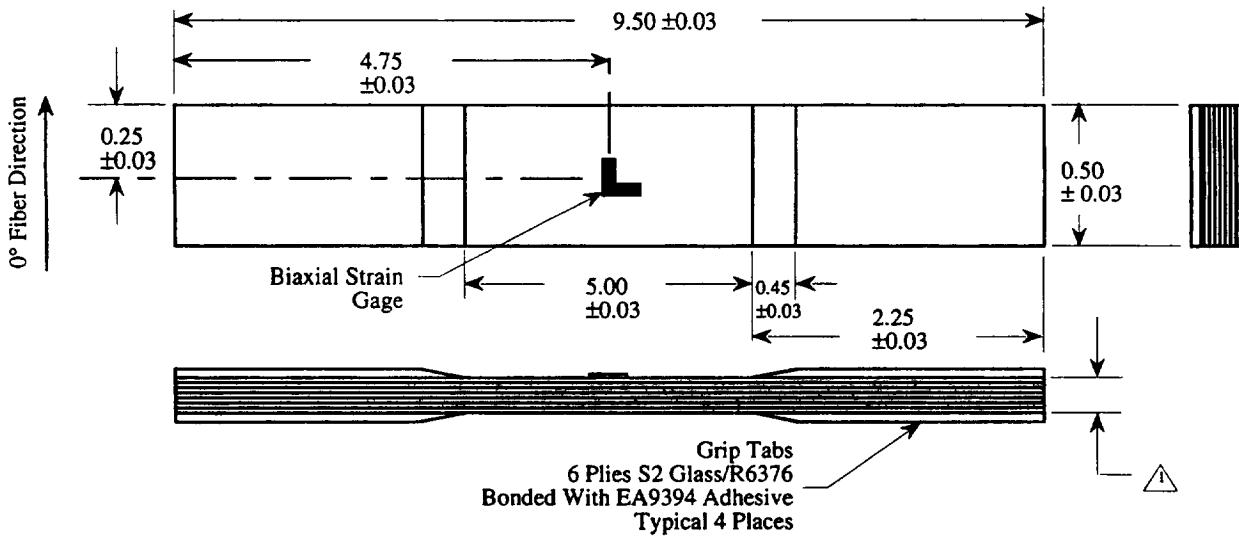


Figure 7. Panel 6, Layout for ± 45 In-Plane Shear $[+45/-45]S$, $T_{nom} = 0.217"$, Woven Material.



\triangle $t(\text{nom}) = 0.0576$ in. = 10 plies $\times 0.00576$ in/ply for tape laminates.
 $t(\text{nom}) = 0.0723$ in. = 8 plies $\times 0.00904$ in/ply for woven laminates.

Figure 8. Longitudinal Tension Test Specimen.



\triangle $t(\text{nom}) = 0.1728$ in. = 30 plies $\times 0.00576$ in/ply for tape laminates.
 $t(\text{nom}) = 0.0723$ in. = 8 plies $\times 0.00904$ in/ply for woven laminates.

Figure 9. Transverse Tension Test Specimen.

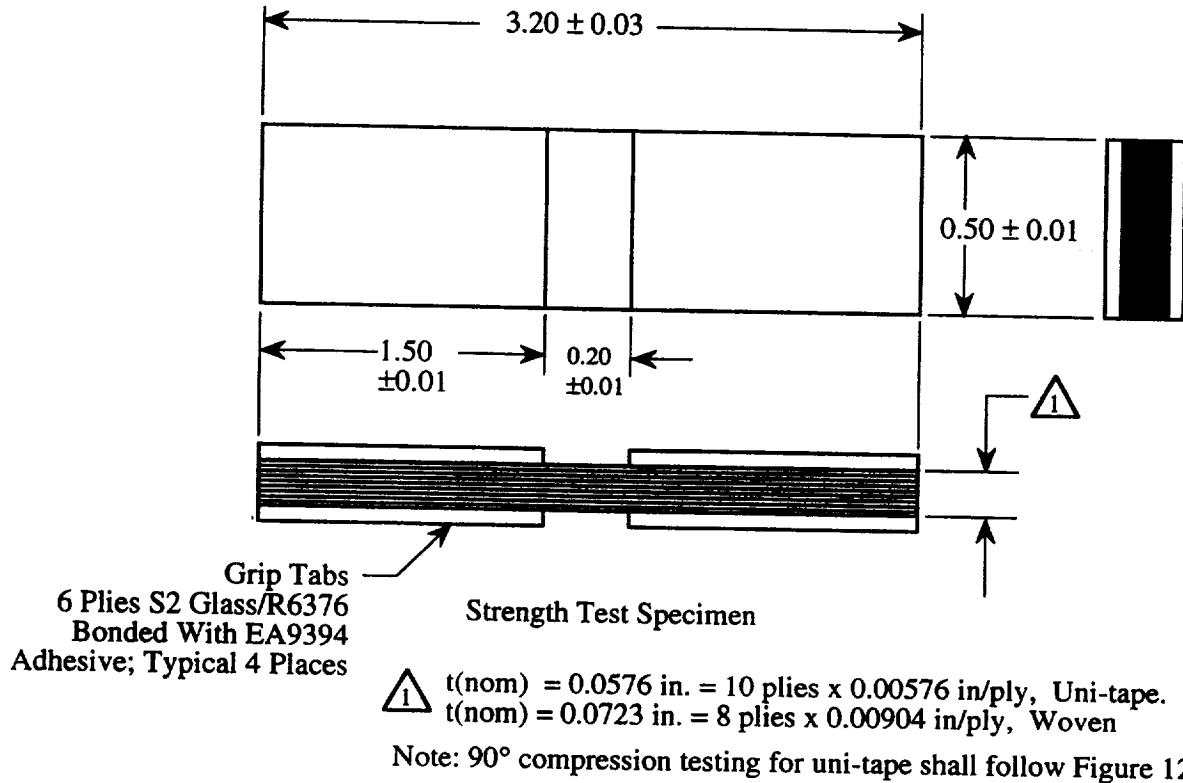


Figure 10. Test Specimen For 0° and 90° Compression Strength Testing.

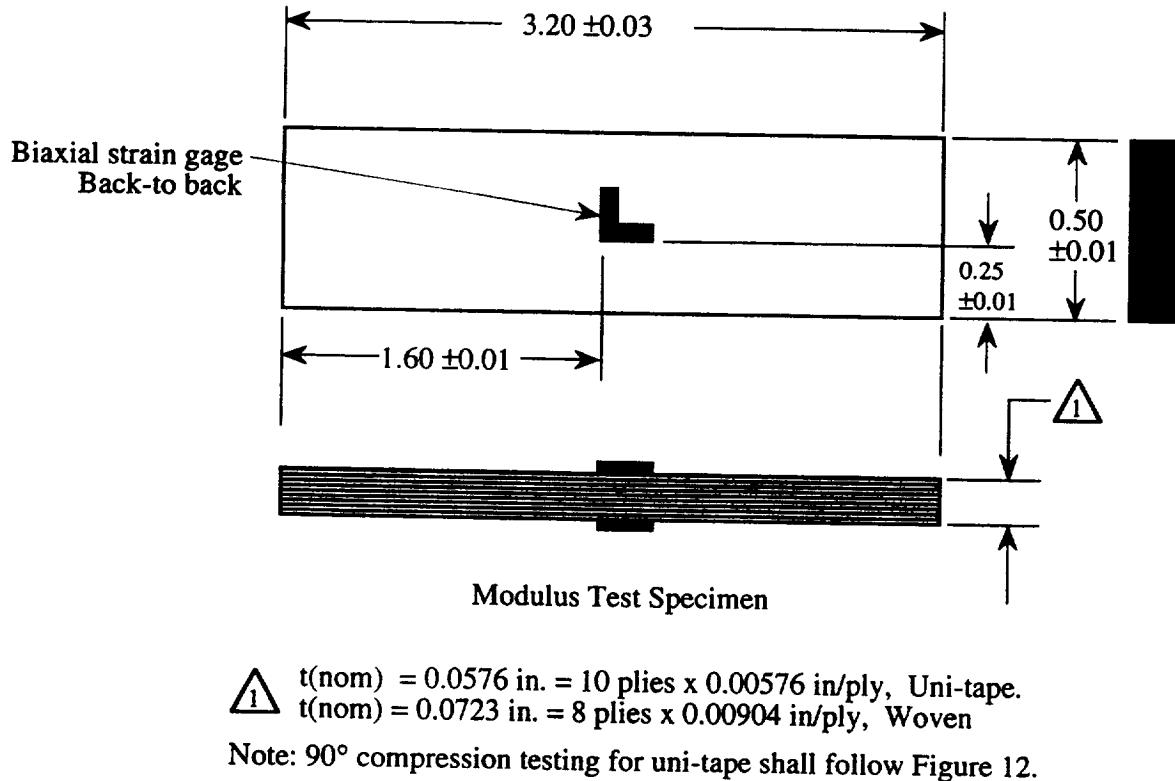
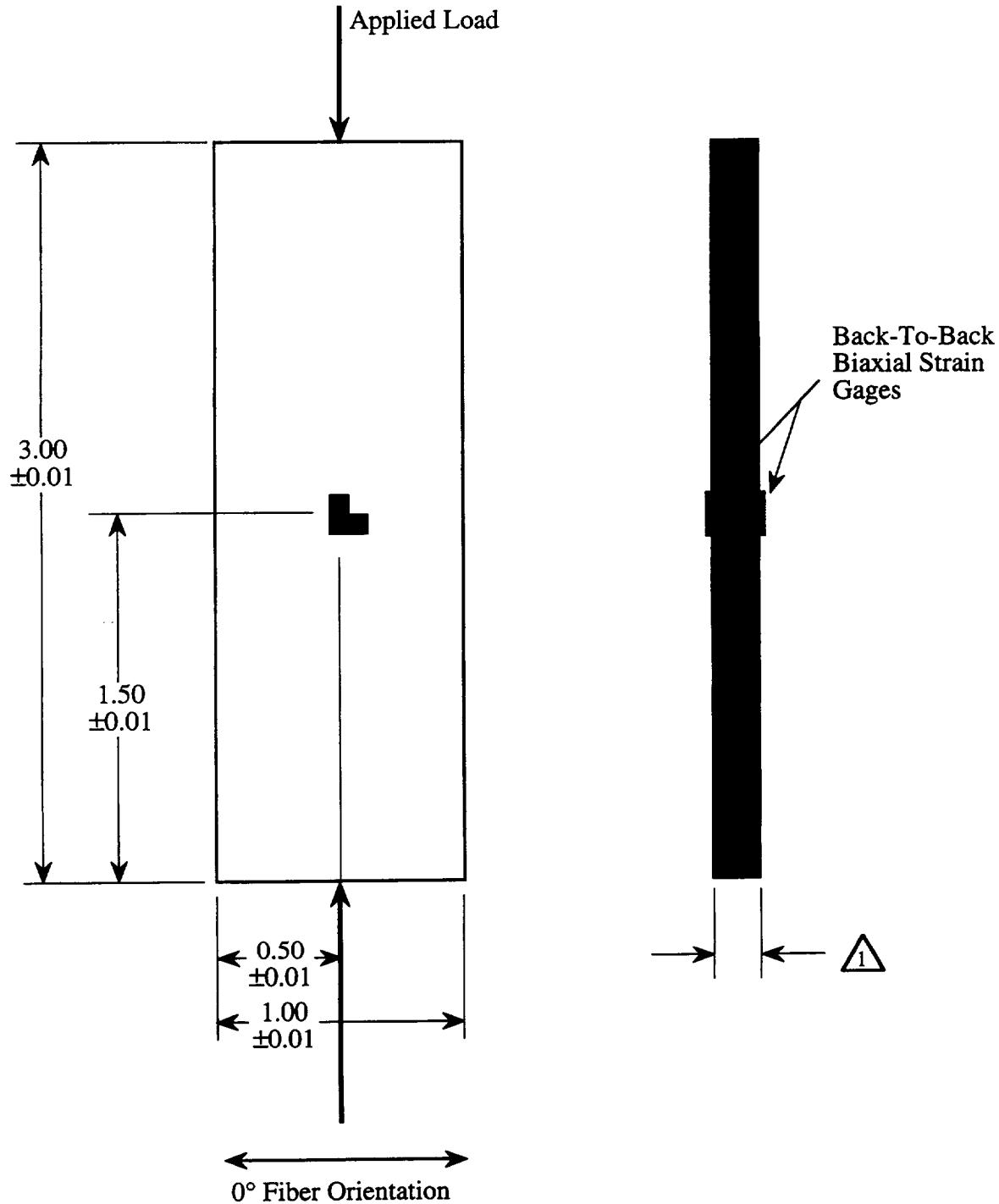


Figure 11. Test Specimen For 0° and 90° Compression Modulus Testing.



$$\Delta_1 \quad t(\text{nom}) = 0.138 \text{ in.} = 24 \text{ plies} \times 0.00576 \text{ in/ply, Uni-Tape}$$

Figure 12. Transverse Compression Specimen For Tape.

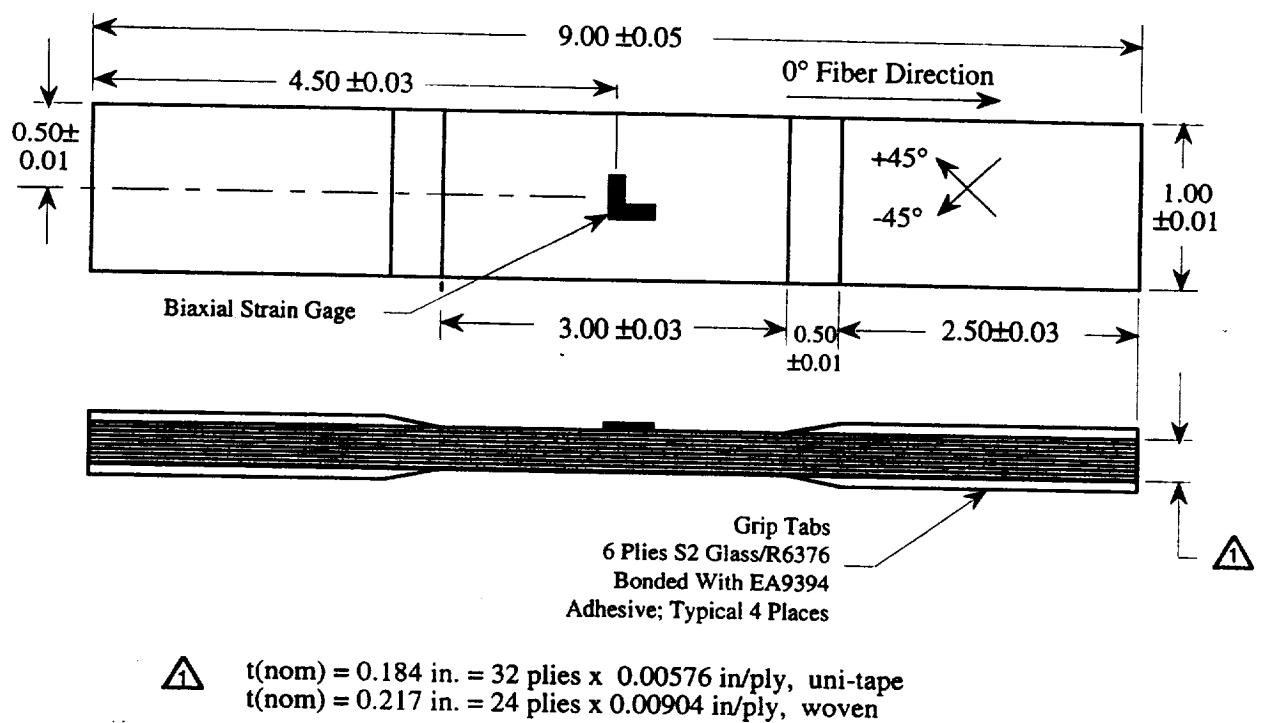
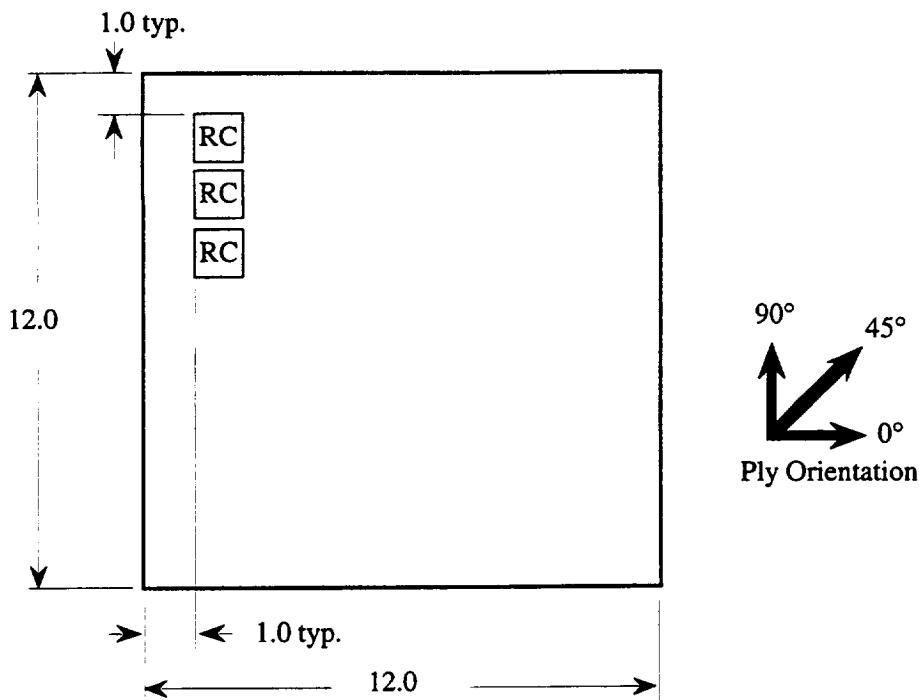
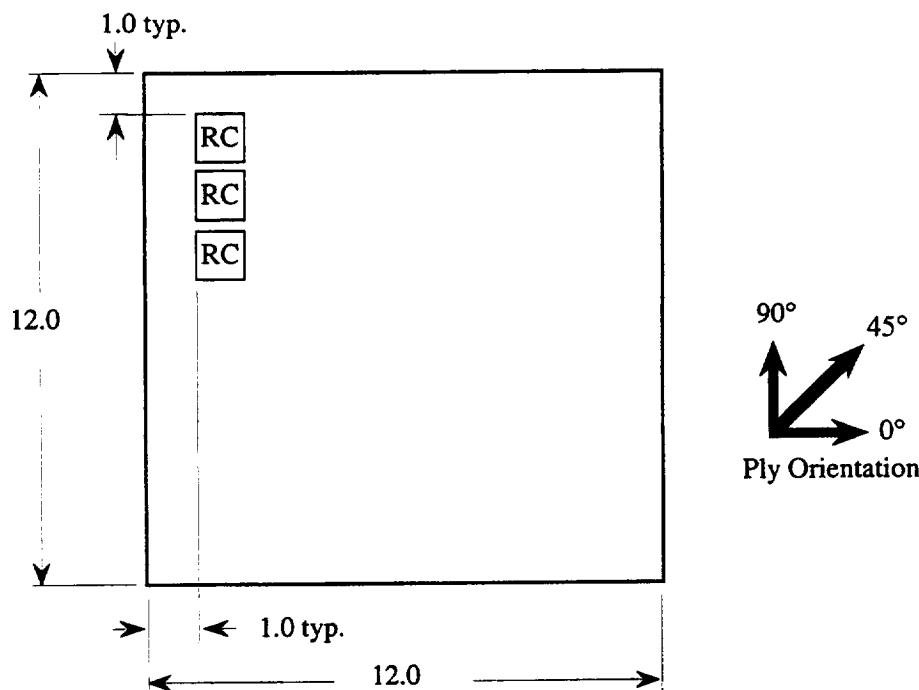


Figure 13. $\pm 45^\circ$ In-plane Shear Test Specimen.



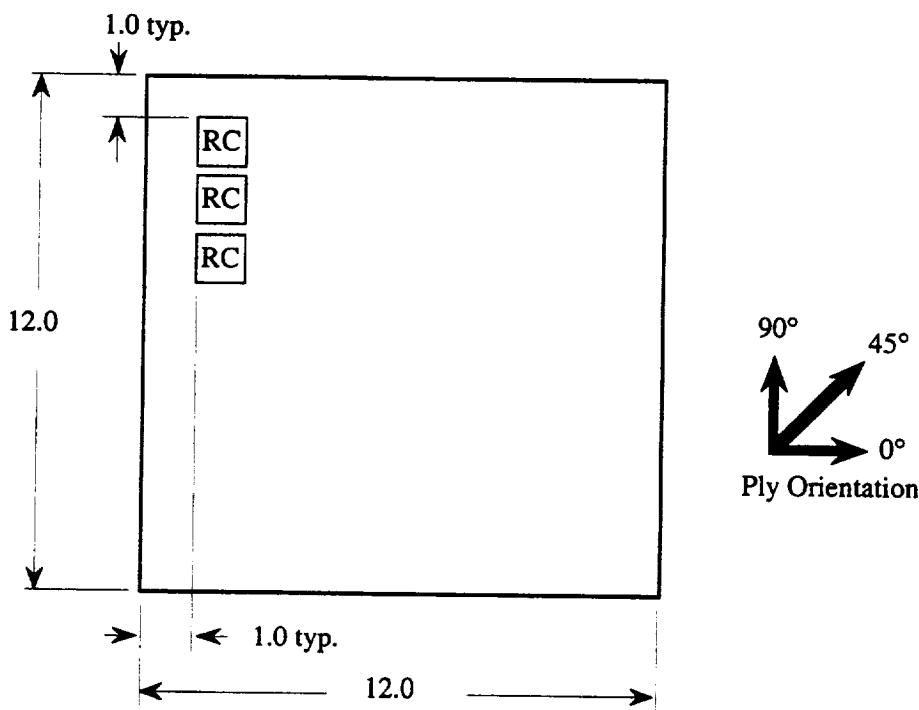
- Notes:
1. Drawing not to scale.
 2. Dimensions are consistent with 0.125" spacing between specimens.
 3. Resin content specimens are 1" x 1".

Figure 14. Panel 13, [0]24, Unidirectional Tape, Debulked Every Four Plies for 15 Min.



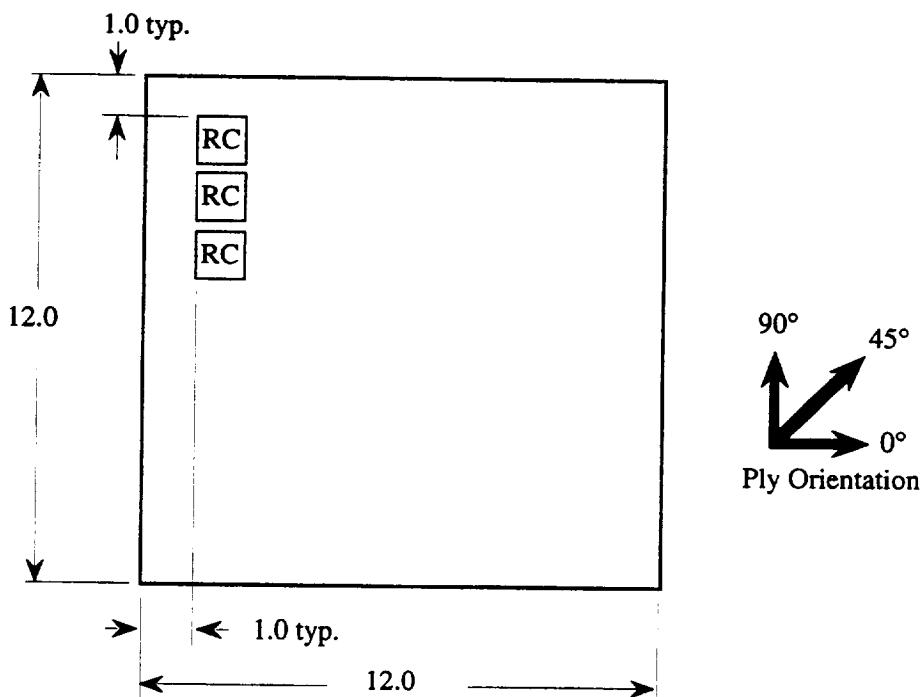
- Notes:
1. Drawing not to scale.
 2. Dimensions are consistent with 0.125" spacing between specimens.
 3. Resin content specimens are 1" x 1".

Figure 15. Panel 14, [0]24, Unidirectional Tape, Debulked Every 24 Plies for One Hour.



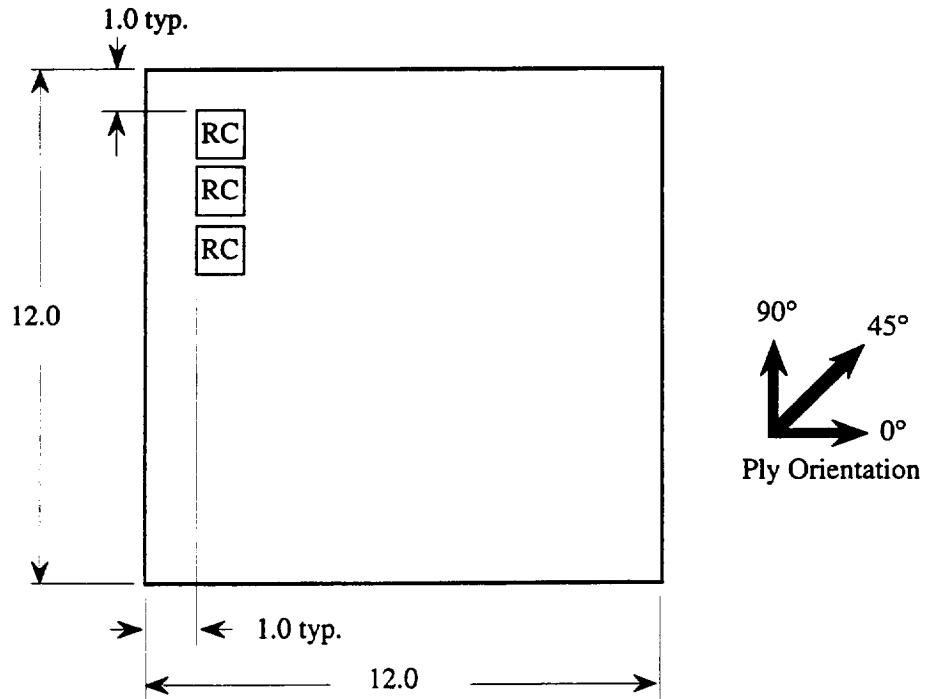
- Notes:
1. Drawing not to scale.
 2. Dimensions are consistent with 0.125" spacing between specimens.
 3. Resin content specimens are 1" x 1".

Figure 16. Panel 15, [(0/90)₆]S, Unidirectional Tape, Debulked Every Four Plies for 15 Min.



- Notes:
1. Drawing not to scale.
 2. Dimensions are consistent with 0.125" spacing between specimens.
 3. Resin content specimens are 1" x 1".

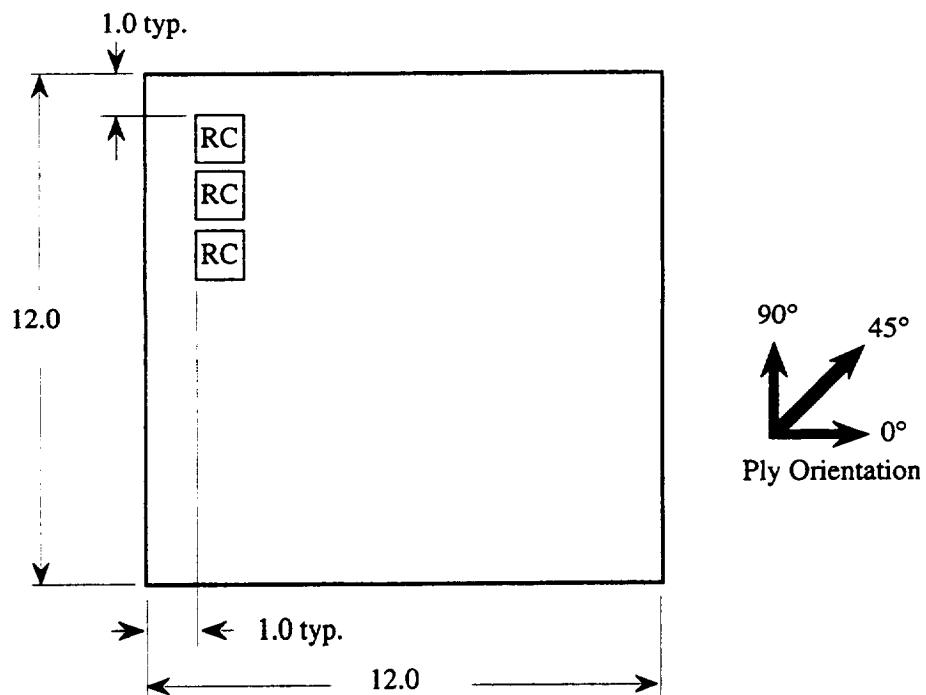
Figure 17. Panel 16, [(0/90)₆]S, Unidirectional Tape, Debulked Every 24 Plies for One Hour.



Notes:

1. Drawing not to scale.
2. Dimensions are consistent with 0.125" spacing between specimens.
3. Resin content specimens are 1" x 1".

Figure 18. Panel 17, [0]24, Woven, Debulked Every Four Plies for 15 Min.



Notes:

1. Drawing not to scale.
2. Dimensions are consistent with 0.125" spacing between specimens.
3. Resin content specimens are 1" x 1".

Figure 19. Panel 18, [0]24, Woven, Debulked Every 24 Plies for One Hour.

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<p>This report summarizes the work performed on the contract NAS1-19347, Task 14. Northrop Grumman Corporation was contracted by NASA Langley to conduct testing on composite materials that cure at low temperatures. These materials are being incorporated into Unmanned Aerial Vehicles (UAVs) to reduce manufacturing costs since it allows the use of low-cost tooling and facilities. Two composite prepreg product forms were evaluated; MR50/LTM25 unidirectional tape, batch 588cu and CFS003/LTM25 woven cloth, batch 1661. Both product forms were manufactured by the Advanced Composite Group, Inc., and were supplied by NASA. Northrop Grumman fabricated, machined, and tested specimens to determine the properties listed in Tables 1 and 2 for the two material systems. In order to generate the properties requested by NASA, Northrop Grumman developed and executed the test matrix shown in Table 3. Additional panels listed in Table 4 were fabricated, inspected, and shipped to NASA for further evaluation. The effects of different debulking procedures were evaluated on laminate numbers 13 through 18. These panels were sectioned at Northrop Grumman to determine the resin content, fiber volume fraction, void content, and density. After sectioning, these panels were shipped to NASA as well.</p>			
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